













# MEDICAL CHEMISTRY

FOR THE

USE OF STUDENTS AND THE PROFESSION:

BEING A

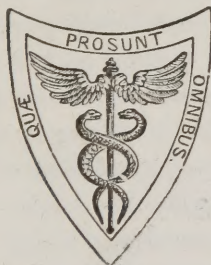
## MANUAL OF THE SCIENCE,

WITH ITS APPLICATIONS TO

TOXICOLOGY, PHYSIOLOGY, THERAPEUTICS, HYGIENE, &c.

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## PREFACE.

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THE Author has felt much embarrassment in the discharge of his duties as a teacher of Chemistry to a medical class, from the want of a suitable text-book. The works on the subject are sufficiently numerous, but they treat the science abstractly, and are for the most part too heavy for the purposes of the medical student.

So far as he may judge, there is wanting a book which directs the attention of the novice to the intimate connections between this science and medicine—something which may interest his mind in the subject of Chemistry by pointing out its relations to physiology, therapeutics and practice.

The attention of the profession has been excited, within the last few years, by the labors of the German and French chemists, in physiology and the kindred sciences; but these researches are in some measure unappreciated among us, from the want of chemical knowledge, and the apparent difficulty in acquiring it. The author has been desirous of offering a means of dispelling this difficulty, by the preparation of a manual, which may serve as an introduction to more elaborate essays.

He does not lay claim to originality, but is more ambitious to be useful; and his highest satisfaction will be found in having contributed something towards the introduction of chemical science into medicine.

D. P. GARDNER, M. D.

PHILADELPHIA, *July* 1848.



# PREFACE

The history of the United States is the history of a people who have been the recipients of a special blessing from the hand of a beneficent God. The words of the Psalmist are fulfilled in our country: "For thou, O Lord, art good, and thy mercy is great: thou wilt not contend with the wicked, neither wilt thou hate the man of violence; for thou, O Lord, art merciful, and thy compassion is great: thou wilt not contend with the wicked, neither wilt thou hate the man of violence; for thou, O Lord, art merciful, and thy compassion is great."

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BY THE AUTHOR

NEW YORK

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# MEDICAL CHEMISTRY.

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## INTRODUCTION.

CHEMISTRY is the science of atoms; it not only investigates their properties, but their relations to one another, and the influence of certain forces on them. There are, therefore, two capital divisions of the subject, the history of matter and the nature and effects of force. Matter, in this science, is supposed to consist of extremely minute particles or atoms, separated from one another by a rare medium called ether, and to possess impenetrability, gravity, porosity, inertia, and indestructibility. Force, on the other hand, is convertible, and the result produced by any application of it may be either the motion of a mass, the evolution of heat, light, electricity, or molecular disturbance, these depending on the degree and manner of application of the force. Of the chemical forces we know nothing except by their action on matter, which is either that of attraction or repulsion; therefore for their evolution chemists admit the presence not only of ordinary matter, but also of a rare medium called the luminiferous or universal ether, occupying space, and present in all bodies; in the motion of which the phenomena of heat, light, and electricity are apparent. The atom of the chemist is, therefore, surrounded by an atmosphere or envelope of ether, and is subjected to any action which affects this medium. The term *imponderable*, formerly employed to designate heat, light and electricity, is not now used, for these are considered forces, and not particular kinds of matter.

DEFINITIONS.—The terms employed in stating the chemical views of matter require to be defined to obviate any misunderstanding.

*An atom* is the ultimate portion of a body, beyond which further division is impossible; it is spheroidal, of a known weight called its atomic weight, proportional or combining number; it

is enveloped by ether, and has inertia. It is said to be elementary or simple when it cannot be changed by heat, light or electricity; compound when it can be separated into two or more parts by these forces. It is extremely minute, as may be conceived from the fact that a globule of blood is one four-thousandth part of an inch in diameter, yet consists of three parts—a central nucleus, an envelop of coloring matter, and a proper covering, and that the nucleus, consisting of globulin, contains 1661 atoms. Ehrenberg also announces that ten thousand thousand millions of Baccillariæ occupy but one cubic inch. Yet each of these animals consists of many complicated parts. All chemical changes occur among these atoms.

*Matter* consists of an aggregation of atoms having *extension* or occupying space; it is compound or elementary, in a chemical sense, as it is composed of combined or elementary atoms. Its particular form, whether it be a gas, a fluid, or solid, depends upon the condensation or separation of the atoms. In consequence of the atoms being separated from one another, there exist spaces occupied by ether between them, which give to the mass the quality of porosity. It also appears to be continually subject to two states of force, attraction and repulsion, the former of which tends to bring the particles together, and the latter acts to disunite them.

*Porosity*.—This term expresses the fact, that all matter, and forms of matter, are full of pores or spaces containing ether, into which bodies can pass under favorable circumstances. The extent of the porosity depends upon the condition of the body, gases and vapors being remarkably porous, and allowing other gases to flow through them with little obstruction, fluids being less porous and solids least so.

*Impenetrability*.—The property one portion of matter possesses of occupying space, to the exclusion of all other bodies. It refers to the absolute parts, and not to the interstices. Numerous illustrations of this property are at hand, but a very striking one is as follows:—If a tumbler be inverted into water, it may be pressed down several inches without the water rising into it, because the contained air is impenetrable. On this principle, the diving bell is constructed.

*Gravity*.—All matter has weight, and exerts pressure. This pressure is termed gravity; it is developed to a remarkable extent in bodies of great bulk, as the earth, sun and planets.

*Inertia*.—An indisposition to rest or motion; incapacity to take on motion, or to stop if in movement. It is necessary that a force be acting to produce motion, and that an equal force or resistance be employed to arrest it. The world and planets offer sublime illustrations of the inertia of matter. These being ori-

ginally thrown into movement, continue it in the absence of a sufficient impediment to their courses. This property holds for atoms likewise.

*Indestructibility* is a property of atoms. It expresses the fact that an atom of matter cannot be destroyed; it may unite in a variety of ways under the influence of light, heat, or electricity, but it reappears when these forces are removed. Thus the fire does not destroy the atoms of carbon, but merely overcomes their particular combination. If we take means to collect them, they will weigh as much as before combustion.

*Ether*.—This is an extremely rare body, which possesses no appreciable weight, is supposed to envelope every atom, and occupy all space. In it the undulations or movements producing heat, light and electricity, take place. Its existence seems to be more than hypothetical, for it has been shown that the flight of several comets is impeded by an agent which is too rare to disturb the movements of the planets. The comets, which are vaporous masses, being more readily influenced by a trifling resistance, are soonest affected; in consequence of this action, the comets of Biela and Encke have had their orbits contracted, and their periods lessened each revolution, the former by one, and the latter by two days. The density of a body depends upon the proportion of ether to matter, gases containing the greatest amount interposed between their particles, and solids the least.

*Specific Gravity*.—All matter has weight or gravity, and this property depends upon the attraction of the earth, but every species of matter is not equally attracted. An ounce phial of quicksilver weighs very much more than the same amount of water, oil, or other fluids. A cubic inch of gold weighs more than twice as much as the same bulk of iron, lead, or zinc. In considering the gravity of a body, it is, therefore, necessary at the same time to remember its bulk, and this is done whenever the specific gravity is given—for the specific gravity (*sp. gr.*) is the expression of the weight of a body as compared to its bulk. Water is taken as the standard in solids and fluids, air in gases and vapors. The solid or fluid is, therefore, compared to water as unity, and if it be heavier, the proportion as compared to a similar bulk of water is given, and this constitutes the specific gravity. Thus if we wish to ascertain the specific gravity of a fluid, we select a bottle capable of containing exactly 1000 grains of water, and this being filled, weigh—then the bulks being the same, the specific gravities will be directly as the weights. If the fluid weigh 1800 grains, its specific gravity will be 1.8 that of water being 1,—or 1800 that of water being 1000. So by this simple means, the *thousand-grain bottle*, the specific gravities of fluids can be taken. We may also employ the buoyant power of liquids, for this is

found to be directly as their densities. On this principle the *hydrometer* and the specific gravity beads are constructed.

The *hydrometer* is a vessel of metal or glass, consisting of a stem, and two ovoidal bulbs, the lower usually small, and filled with shot or quicksilver, to keep the instrument (*fig. 1*) in an upright position in fluids. The stem is graduated, and the whole is of such weight that it floats in most liquids, but in different degrees, the stem being more or less submerged. When the fluid is light, it sinks lowest, and when heavy, is buoyed up, and we may determine the specific gravity by reading the marks of the scale on the stem.



The specific gravity of a solid is readily obtained, by weighing it first in air, then in water, finding the difference, and dividing the first number by this. The difference in this case is the weight of an equal bulk

of water.

In the case of gases and vapors, a bottle of certain dimensions is taken; this is weighed when full of air, and also weighed after it has been thoroughly emptied under the air-pump; the difference gives the weight of the air irrespective of the glass. If now it be filled with vapor of water, oxygen or any other gas, and weighed, the increase of weight will be due to the gas employed, and by taking air as unity, the specific gravity is readily determined.

In all these cases, the temperature is to be considered, for bodies dilate by heat and become of less specific gravity by their enlargement. The temperature adopted as a standard, is  $60^{\circ}$  F.

The foregoing are the essential properties of atoms and matter, but there are others which are *particular* or *dependent*. The particular properties, as combustibility, color, malleability, ductility, &c., it is the business of the chemist to discover by experiment, and record as a test of the presence of any given substance. The dependent properties arise from peculiar circumstances; such are elasticity, compressibility, expansibility, cohesion, for the same substance may or may not exhibit these qualities. Water is little elastic, but steam is highly so; the one has cohesion, the other little or none. The dependent properties of matter, with the state of combination and other considerations, depend upon the action of the chemical or molecular forces, heat, light, and electricity; hence it is a matter of great importance to understand their effects, and this study constitutes a necessary portion of chemistry.

# PART I.

## THE CHEMICAL FORCES.

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### HEAT.

*Heat* and *Caloric* are terms often used indiscriminately, but they were originally employed to designate things entirely different, caloric being a name given to the agent which produces the phenomena of heat—and heat to some of the effects so produced, as the expansion of bodies, and the sensation of warmth.

The cause of heat was formerly attributed to the action of extremely minute imponderable atoms, which had a self-repellent power, and which, intruding between the molecules of matter, caused them to be torn asunder. In the present day, it is attributed to movements in the atoms of the ether which occupies the interstices of matter. These movements are similar to the vibrations which produce waves, but on a very minute scale. They are also propagated in the same way as waves from a centre, diminishing in intensity inversely as the squares of the distances. That is to say, the heat which produces an effect equal to  $100^{\circ}$  degrees of the thermometer at one foot, will produce but  $\frac{1}{4}$ th of this effect at 2 feet,  $\frac{1}{9}$ th at 3 feet,  $\frac{1}{16}$ th at 4 feet, &c. This law is true for all central forces, or those in which the effect lessens with distance, as light, gravity, heat.

Adopting the ethereal hypothesis of caloric, it will be evident that whilst a substance is heated, and its ether thrown into vibrations, the atoms of the body will be forced apart, and the motion will be communicated to all the neighboring ether and matter. In virtue of the first effect, all bodies expand or become enlarged by heat, and the second effect is termed the radiation or propagation of heat. To these two effects of expansion and radiation, nearly all the phenomena of heat belong. Moreover, the difference in intensity of heat depends upon the strength of the vibrations being greater as the temperature rises. Any application of force may throw the calorific ether into vibrations; it is done by pressure, as when gases are suddenly condensed; it is done by friction in filing a piece of metal; it is also produced by electrical action, as in the passage of a current of galvanism through a



piece of thin platina, &c., and in a variety of cases, when chemical union occurs, as in the common fire. In these and every other case, there is a force acting upon the ether, and not the introduction of new matter, as according to the corpuscular theory.

*The effects of Heat.*—As we have already remarked, the principal effects of heat are *expansion* and *radiation*. Other consequences flow from the undulatory theory; thus as the amount of ether present, in any form of matter, is dependent upon its peculiar properties, it is evident that the same force will act unequally upon different kinds of matter, producing different amounts of expansion, and acting in different times. Thus an equal weight of mercury is heated before the same fire, thirteen times sooner than water. In consequence of this difference, bodies are said to have different *capacities for heat*, or to have different *specific heats*. When substances are condensed, or pass into a rarer state, it is found that heat is given out, or a sensation of coldness is produced; these phenomena are attributed to effects occurring in a contained or hidden heat, not to be measured except during the act of change; this part of the subject is termed *Latent heat*. That there is such a state of heat, it is impossible to conceive on the ethereal hypothesis, but as there are many important facts grouped under this head, the term is here preserved. The actions which produce the phenomena of latent heat, will be considered under their proper head. Heat also exerts considerable action in the chemical union of bodies, but this is not now under consideration.

The study of heat, therefore, divides itself into four parts:

1. Expansion.
2. Radiation.
3. Specific heat.
4. Latent heat.

### § 1. EXPANSION.

Expansion is the increment in size which elementary bodies undergo by additions of heat; it does not always occur in compound bodies, because decomposition, evaporation, or some particular effect may arise to disturb the operation of the agent. The expanded body returns to its original dimension when cooled. It is demonstrated by a number of cases: thus, if we adapt a copper ball to a ring, through which it just passes when cold, and heat it, the ball will expand and become so enlarged that it cannot pass the ring, but on cooling, again returns to its original size. This experiment may be taken as a demonstration of several important facts. It shows that the copper ball does not

consist of atoms only, of an unchangeable magnitude, but that it likewise contains between them spaces susceptible of enlargement; the spaces occupied by the ether. The enlargement is not due to the addition of matter, but to the thrusting out of the atoms of the copper by actions taking place in the ether of the spaces. These are of a temporary nature, and the atoms come together again as soon as the vibrations cease. To bring the parts again together, it is generally conceived that a new force of attraction, the reverse of that which separated them, comes into operation. So that the atoms are subject to two forces, and the bulk at any time represents the relation between them. The force of *repulsion* has been shown to be heat; the force of *attraction*, or *cohesion*, is thought to be electricity. The existence of this second force is necessary to return the body to its original size; otherwise, the motion commenced in the ether would continue for ever in consequence of the inertia of matter. A competent force must therefore operate to destroy the motion produced by heat, and bring the body to its former state. The volume of a substance always depends upon the relation of these two forces; where cohesion is greatest, the solid is the consequence; when it is less, the fluid: whilst aeriform bodies possess but little cohesion. In consequence of the different resistance offered by the cohesive force to the disruption of the atoms of bodies, the amount of expansion in objects differs exceedingly.

*Expansion of Solids.*—Solids expand very differently. Thus, between  $32^{\circ}$  and  $212^{\circ}$  of Fahrenheit's thermometer, glass expands about  $\frac{1}{1100}$ th of its length, iron  $\frac{1}{819}$ th, gold  $\frac{1}{662}$ th, brass  $\frac{1}{533}$ th, silver  $\frac{1}{524}$ th, and lead  $\frac{1}{351}$ th.

The amount of expansion for high degrees of heat is larger, the rate not being uniform except at low temperatures. Iron at  $212^{\circ}$  expands  $\frac{1}{5076}$ th of its length for one degree, but at  $572$  as much as  $\frac{1}{40672}$ th.

The expansion takes place with immense force, and means have to be taken in the erection of metallic bridges to guard against the consequences. It also affects the length of the pendulum, causing it to beat slower as it becomes heated. For this there is a remedy in the construction of the compensation pendulum. The gridiron pendulum consists of an arrangement of iron and brass rods, such that any increase of length in the iron may be exactly compensated by an expansion in the brass in an opposite direction, the effect of which is that the bob or weight is kept precisely at the same distance from the point of suspension, and the instrument beats with perfect regularity at all temperatures.

The expansion of metals is made use of in the arts, as in tiring wheels, and for other purposes. The tire being hot when adjusted to the wheel, contracts upon the felloes as it is cooled,

binding them firmly together. Professor Daniell has also employed it for the construction of a pyrometer, to measure high temperatures by the expansion of a platinum bar fitted to a case of plumbago. The heat enlarges the metal, causing it to thrust up a wedge placed above it in the case, and this advance is measured by a gauge, and shows how much the platinum had expanded by heat. By this pyrometer it appears that the melting point of copper is  $1996^{\circ}$  F., gold  $2200^{\circ}$ , cast iron  $2786^{\circ}$  F.

*Expansion in Liquids.*—All liquids expand by the application of heat, but they do not expand equally, nor does the same liquid dilate regularly for similar increments of heat, but faster as the temperature rises.

The unequal expansion of different fluids may be readily demonstrated by taking three large thermometers, and filling them respectively with alcohol, ether and water. If these be introduced into a water bath of the same heat, the ether will rise or expand most rapidly, the alcohol next, and the water least. In this way it has been shown that from  $32^{\circ}$  to  $212^{\circ}$  F., or for 180 degrees of heat, water expands  $\frac{1}{225}$ d of its bulk, olive oil  $\frac{1}{12}$ th; alcohol  $\frac{1}{9}$ th; and sulphuric acid  $\frac{1}{17}$ th.

In this small amount of heat, the difference in the rate of expansion is small, but at higher temperatures the rate is very unequal; thus the absolute expansion of quicksilver from 32 to 212 is  $\frac{1}{55}$ th of its bulk; from 212 to  $392 = \frac{1}{54}$ th and from 392 to  $572 = \frac{1}{53}$ d. This applies to all fluids.

As fluids cool, they contract steadily until they become solid, except in a few remarkable cases. We find that water contracts only to  $39\frac{1}{2}^{\circ}$  F.; it then expands and becomes enlarged by  $\frac{1}{9}$ th its bulk before freezing. The type metal used in casting letters and cast iron has the same property. The temperature at which this anomalous expansion takes place, is called the "*point of maximum density*." It occurs in fluids which crystalize as they solidify, and is commonly attributed to a change in the molecules when they are about to take on the symmetrical adjustment of a crystal. It is a phenomenon of great importance in nature, for did not water expand in being converted into ice, that body would sink to the beds of rivers and seas, and in consequence of the poor conducting power of water for heat, it could not be thawed during the hottest summers in a deep river, so that the water-courses would be obstructed, life destroyed, and an injurious influence exerted on climate.

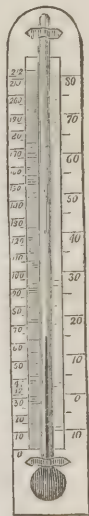
The expansion of fluids alters their specific gravities. If a measure accurately full at  $40^{\circ}$  F. contain 1000 grains of water, and it be heated to 100 F., in consequence of expansion, a portion will flow out leaving the vessel full, but containing only 985 grains; hence the fluid will be lighter than at  $40^{\circ}$  F. It is, therefore,

necessary, to insure accuracy, that the temperature of a fluid, and especially a gas, should be given when we are treating of its bulk.

The principal use made of the expansion of fluids in the arts is in the construction of the thermometer, but it might also be employed as a mechanical force.

The *thermometer* is employed to mark variations in temperature, to determine questions in meteorology and chemistry, and is useful in regulating the temperature of the air in the sick chamber, and of baths. The mercurial thermometer is almost exclusively employed in this climate; its principal advantages are the large range of temperature which may be measured by it, from 39 degrees below zero to 662° F; the mercury also expands more regularly at high temperatures than other fluids. Thermometers are also filled with colored alcohol and sulphuric acid. This instrument consists of a glass tube of fine and regular bore, at one end of which is a small bulb. When it is partially filled with mercury, the fluid is heated until it rises to the top of the tube, which is then sealed by melting the glass with a blow-pipe flame. It contains only the fluid by the expansion of which we measure temperature, and is free from air. To this is next to be attached a scale for marking the expansion and degree of heat which it corresponds to, but as there is no rule in nature, any one may contrive a scale. The instrument is represented in fig. 2. We have the scales of Fahrenheit, Reaumur, De Lisle and the Centigrade. The Centigrade and Fahrenheit are now almost exclusively employed. To make these, the glass bulbs are first placed in thawing ice, and a mark made at the point where the fluid rests; they are afterwards exposed to boiling water, and a mark made here also. The thawing of ice and boiling of water always take place at fixed temperatures, at the sea level, and are therefore standards. In Fahrenheit's scale, the thawing point is marked 32°, and the boiling 212° F. In the Centigrade, the first is marked 0° C., or zero Centigrade, and the second 100° C. This scale contains only 100 degrees between the two points. Fahrenheit's scale has 180° between them. The distance between these stationary marks is now divided on a piece of metal, wood, ivory or convenient material, and attached to the glass. For degrees above or below these points marks are made of the same value, or, if we are very particular, other stationary points are ascertained and marked on the scale. These are the boiling points of mercury, 662° F., pure ether 96° F., or alcohol 173° F.; and the temperatures of

Fig. 2.





artificial mixtures of snow, and various proportions of salt and other substances are also employed. Authors usually express the scale they allude to by affixing the letters F. for Fahrenheit; C. for Centigrade, and R. for Reaumur; the sign of — (*minus*) is also employed for temperatures below the 0 or zero, and sometimes + (*plus*) for those above.

It is often necessary to convert the measures of Centigrade into those of Fahrenheit, and the reverse. To convert Centigrade into Fahrenheit, we multiply by 9 and divide by 5, and add 32, if the degree be above 0. For as  $100^{\circ} \text{C.} = 180^{\circ} \text{F.} :: 1^{\circ} \text{C.} = \frac{9}{5} \text{th F.}$  or nearly two degrees. To convert Fahrenheit into Centigrade, multiply by 5 and divide by 9, subtracting 32 for temperatures above zero. In the scale of Reaumur, there are but  $80^{\circ} \text{R.}$  between the boiling and freezing of water ( $0^{\circ}$ ); this scale is therefore converted into Fahrenheit by multiplying by 9, dividing by 4, and adding  $32^{\circ}$  as before.

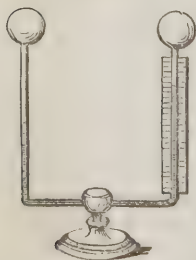
*Expansion in Gases.*—Gases and vapors, at temperatures remote from their points of liquefaction, expand to a remarkable extent by the application of heat. In consequence of the feeble cohesion they possess, this expansion is nearly the same for all. It is about  $\frac{1}{480}$ th of the volume at  $0^{\circ} \text{F.}$ , or  $\frac{1}{492}$ d of the volume at  $32^{\circ} \text{F.}$  Moreover, the rate of expansion is nearly uniform at all temperatures, and whether the body be subject to condensation or not.

In consequence of the great expansion of aeriform matter,  $460^{\circ} \text{F.}$  of heat, increasing one cubic inch to two cubic inches, their specific gravity is continually subject to variation. Heated air being lighter, rises as we observe in chimneys. This property of air is the cause of the disturbances in the atmosphere, called winds, and is also the principle whereby ventilation is accomplished. For this purpose all that is necessary, is to provide egress for the heated air in the upper part of the room, to which it naturally rises, and regulate the supply of fresh air below.

Hot air having a great ascensional power from its diminished specific gravity, was first used in balloons, by Montgolfier, in 1782.

In consequence of its rapid dilatation, it was employed to form thermometers by Galileo and Sanctorio. Such instruments are of no use from the varying pressure of the air which acts on the volume of the gas also. Hence the rise or fall in the air thermometer, arises both from changes in heat, and in the pressure of the air. Leslie's differential thermometer (fig. 3) having the fluid entirely separated from the atmosphere,

Fig. 3.



is not subject to this disturbance, but can only be made use of in particular cases, not being serviceable as a general thermometer.

Liebig conceives that the difference in activity, between the inhabitants of temperate and torrid localities, depends upon the different weights of air, especially oxygen, in equal bulks of the atmosphere. As the capacity of the lungs will be the same, he urges that the quantity of oxygen entering to aerate the blood, will be less in the torrid zone, overlooking the fact that the temperature of the interior of the body will be nearly similar in both situations.

## § 2. RADIATION.

When a hot body is brought into a room, we find that the heat is sent forth in all directions. If a thermometer be employed to measure the heat thus passing out, it will be found that the degree will vary with the distance, being inversely as the square of the distance, and that the temperature will be the same at equal distances around the mass. From these facts we infer that the heated body is a centre of force from which an impression is propagated in spherical waves. The sun is a brilliant instance of this sort of radiation. The word radiation was originally introduced in connection with the hypothesis, that heat and light were molecules passing off in straight lines called rays. The influence is not on the particles of air, for radiation takes place through a vacuum, and in the interplanetary spaces which contain no air, it is an affection of the universal ether, the particles of which being thrown into vibrations, produce a wave. This kind of radiation, distinguished by the term *free radiation*, takes place chiefly in gases, and occurs in them without heating their particles. But as ether exists everywhere, a heated body produces undulations in fluids and solids also, therefore radiation occurs in these; but it is not a vibration of the ethereal particles only, but of the material atoms also, and the body becomes heated and of less specific gravity. Radiation is divided into three parts:

1. Free Radiation.
2. Interstitial Radiation or Conduction.
3. Convection of heat.

**FREE RADIATION.**—Every heated body produces free radiation, but substances appear to differ in the rapidity with which the heat is thrown out. It was stated by Leslie, that the facility of radiation depended upon the nature of the body, and upon the surface; and that when it was black, or of a dark color, or rough, it radiated faster than when bright, or of a light color.

Melloni concludes that hammering a surface alters its *emissive*



power, but that mere color cannot be said to do so. Scratching a hard surface also hastens radiation, by offering more points of departure for the radiations, but scratching a soft surface impedes it. In connection with this difference, is the reverse quality of absorbing heat, or the facility with which a body becomes warmed. As might be inferred, good radiators, as coal, lamp-black, plumbago, are also remarkable absorbers of heat, or become rapidly warmed.

The radiation is much faster from a substance at a high temperature than at a low one, or, in other words, the rate of cooling is much faster at high temperatures than when the substance is but slightly heated.

When the least deviation in temperature exists between bodies, the operation of radiation comes into play, and as from a variety of causes, changes of temperature are perpetually occurring, it is customary to admit that interchange of heat by radiation is continually taking place. This position constitutes the ground of the "*theory of the exchanges of heat*," and offers an explanation of the fact that there is a constant effort in bodies and all masses, whether of the earth or planets, to reach an *equilibrium of temperature*. The formation of dew in the evenings of summer, was explained by Dr. Wells on this hypothesis. It occurs only on clear, calm evenings, for it is necessary that the earth should be chilled by radiation to cause the moisture of the air to fall to its surface; and it does not take place when there are clouds, for these radiating back to the earth, hinder the necessary refrigeration.

The propagation of radiant heat is, according to the undulatory theory, accomplished by extremely minute waves set up by the vibrations of the ether, in the same way as the motion of a violin string produces waves in the air, and the phenomenon of sound. These waves do not much exceed those of light in dimensions, for they move with them, and they pass probably with the same velocity of 195,000 miles in a second of time. Nor do these agents resemble one another in such points only, but in nearly all their properties, differing in their effects and relations to matter chiefly. Thus we find that radiant heat, like light, is reflected by some bodies, refracted by others, that it may become absorbed like light falling on a black uneven surface, and that it also exhibits the phenomena of polarization. In their origin they are also closely associated, for light is seldom, if ever, emitted by bodies without heat. There is also an intimate relation between the temperature of a body and the color of the light which it throws out, as the heat rises, the light becoming developed.

*Reflection of Heat.*—The undulations of heat or light falling on a polished surface, have their course changed. This may be

demonstrated by holding a mirror before a fire so that the light is reflected on one's face; it will be found that heat passes with it. If the polished surface be plane, the direction is merely changed. The change of direction is according to a simple law, which also applies to light and all kinds of motion; the angle formed by the coming or *incident* light, or heat with a line perpendicular to the reflecting surface, is the same as the angle formed by the same line with the receding or reflected ray. In figure

Fig. 4.

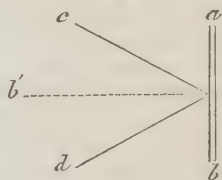
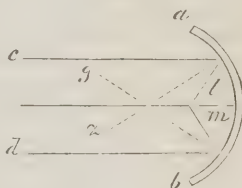
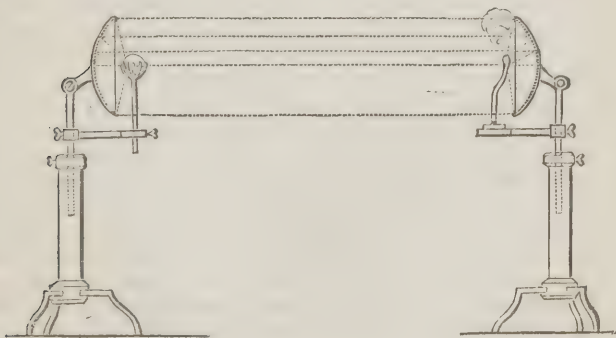


Fig. 5.



4, *a* is a plane metallic mirror, *b'* is a line perpendicular to its face, *c* is the direction of the incident ray, and *d* is the new path of the reflected ray. Now, according to the law, the angle formed between the ray *c* and the line *b'*, is the same as that between *d* and *b'*. This holds true for every reflecting surface. If it be curved as in *a b*, (Fig. 5,) the light and heat will not be merely dispersed, but collected into a point; for, let *c d* be two rays striking the surface, let *g z* be lines representing perpendiculars at the points where the rays fall, therefore the direction of the reflected rays *l m* will be such that the incident rays form the same angle with the perpendiculars as these do. If we draw out the direction of the rays, under such circumstances, we find that when they are parallel, they will be reflected to a point. When the agent is light, this

Fig. 6.



point will be brilliantly illuminated; when heat, it will be very hot, because the heat of a number of rays is here condensed. This point is termed the *focus* of the mirror. If the curve be *convex*, or the reverse of the foregoing, which is *concave*, the heat will be dispersed, and not come to any focus. The action of concave mirrors on heat is beautifully illustrated by setting up two mirrors opposite each other, (Fig. 6,) placing in the focal point of one a red hot coal, or ball of iron, and in the focus of the other a little phosphorus, which will be speedily ignited by radiations from the heated matter.

The concave mirror, and especially that with a parabolic curve, has been much used in researches on radiation for the purpose of condensing small amounts of heat, and rendering them perceptible to the thermometer.

*Transmission of Heat.*—As there are bodies which allow light to pass through them, and others which do not, so some substances transmit the radiations of heat, and others obstruct them. The substances which transmit heat are not necessarily those which are transparent. Hence, the term *diathermanous* has been used to distinguish those which allow the radiation of heat to pass; and *athermanous*, for those which are opaque to heat. If we place a piece of glass between a thermometer and the fire, it will obstruct so much heat as to cause a fall in the mercury; but a transparent piece of rock-salt will not cut off any of the radiations. This property of transmitting heat is not dependent on the clearness or color of the body, for perfectly transparent alum or ice cuts off nearly all the heat, being opaque to that agent, whilst dark rock salt, and smoky quartz or mica, allow a large amount to pass.

Another extraordinary fact has been discovered by M. Melloni in the transmission of heat. He finds that the number of rays, out of a hundred, which pass through a medium, depends upon the temperature of the source. Thus colorless fluor spar allows 78 per cent. of the rays from a heated source, as a fire or oil-flame, to pass, and only 33 from a piece of metal, heated to 212° F. Beryl allows 54 per cent. of the former to pass, and none of the latter. In these experiments, he made use of plates  $\frac{1}{10}$ th of an inch thick, and heat from the undermentioned sources. His method of detecting heat was novel, and extremely delicate. He employed for this purpose, a *thermo-multiplier*, consisting of a number of small bars of antimony and bismuth, united in pairs, and from the first and last bars, were copper wires connected with a galvanometer. When one end of the thermo-multiplier was heated, an electric or thermo-electric current was set in motion, which affected the galvanometer, and indicated the degree of heat. The experiments are to be found in Taylor's Scientific Memoirs. The attached table gives the most striking results.

SUBSTANCES EMPLOYED.	Transmitted of 100 rays of heat from			
	An oil lamp.	Red hot platinum.	Copper heated to 734° F.	Copper at 212° F.
Clear rock salt, . . . .	92	92	92	92
Colorless fluor spar, . . .	78	69	42	33
Beryl, . . . . .	54	23	13	0
Iceland spar, . . . . .	39	28	6	0
Plate glass, . . . . .	39	24	6	0
Clear alum, . . . . .	9	2	0	0
Clear ice, . . . . .	6	0	0	0

From these and other facts, it appears that the radiations of heat, derived from different sources, have unlike properties. Whilst nearly all the heat of the sun's rays penetrates the glass of the window, scarcely any of the heat of the fire passes out of the room through it. While some bodies, as alum, are diathermanous to the waves of heat, propagated by an oil-lamp, they are entirely opaque to those from boiling water or copper, at 734° F. Hence Melloni infers, that there are varieties in heat, as in light; that there are heat waves allied to red, yellow, green, blue, and the other rays of light. This is the basis of the theory of the "*Ideal coloration of heat.*" As a matter of course, the heat rays or *heat tints*, have not color, but they have different wave lengths, which, in the case of light, is the cause of difference of color. Just as a pure blue glass transmits only light of that color, so ice transmits only heat from a very high temperature, cutting off the rest by absorption or otherwise.

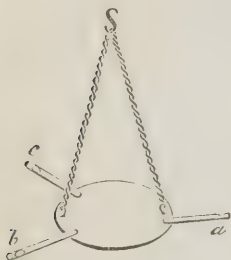
This theory is also sustained by the refraction and polarization of heat, which associate this agent completely with light. To study the refraction of heat, clear rock salt is cut into lenses, prisms, &c., and used, as glasses of the same figure are employed in studying the phenomena of light. Polarization is accomplished by the use of plates of doubly refracting minerals.

INTERSTITIAL RADIATION OR CONDUCTION.—Conduction has been explained as that case of radiation in which the ether of a solid is not only thrown into undulations, by contact with a heated body, but the material atoms are also acted on. In proof of this view, it may be remarked, that the propagation of the heat is very slow, the resistance being great, and the parts of the solid are warmed, and become expanded.

Bodies conduct very unequally, metals being the best conduct-

ors; moist solids and fluids having but little conducting power, whilst gases do not conduct at all. Metals also differ amongst themselves in this property. Gold, silver and copper, conducting very nearly three times as fast as iron, zinc and tin, whilst porcelain, glass and fine clay have little more than one-tenth the

Fig. 7.



power of gold. The unequal conducting power of metals is strikingly illustrated by the following little apparatus (Fig. 7); *a* is a piece of copper about the size of a cent piece, suspended by a wire or chain and hook to any convenient stand: *c*, *d*, *e* are rods of silver, copper and iron, of the same length and thickness, soldered into the central plate; these bear at their ends cup-shaped cavities to hold phosphorus. When a spirit lamp flame is placed under the centre, the heat is conducted with unequal rapidity to the cups, and the phos-

phorus is inflamed in different times.

**CONVECTION OF HEAT.**—Fluids and aeriform bodies are heated chiefly by currents arising in them. The water occupying the lower portion of a vessel, placed on a fire, becomes heated before the parts above it are warmed; in consequence, it dilates and rises through the fluid; thus a current is set up which conveys the heat. The current of heated water may be made apparent by placing pieces of amber in the fluid, which rise with the heated portions. As the strata become cooled at the surface, they descend, and become again heated; thus the circulation is maintained. A vessel of water cannot be heated by applying the fire above, or at the side, whereas metals and conductors may be heated by any of these means. In the case of gases, the dilatation produced by heat is so great that it floats up with considerable force. Winds originate in this way; a bulk of air being heated by contact with the earth, rises, and cold air rushes in to fill the void, and the disturbance is communicated on all sides. The temperature of the air does not arise from the action of radiant heat, but by convection only. This, in a measure, explains the reason of the extreme coldness of mountain tops, and elevations in the air to which the warmed masses scarcely reach.



## § 3. SPECIFIC HEAT.

The term specific heat or capacity for heat is employed to express the singular fact that the rapidity with which equal weights of different substances become heated is very diverse. That is, a pound of quicksilver, of water, and of oil, being placed in similar vessels over the same fire, the first will become heated to  $200^{\circ}$  F., or any practicable degree, thirty times sooner than the water, and fifteen times sooner than the oil. The specific heats of these bodies are, therefore, to each other as 1-15 and 30, or the specific heat (or capacity for heat) of water is thirty times greater than that of mercury.

It follows from this remarkable difference, that if one pound of oil, at  $100^{\circ}$  F., be shaken with one pound of water at  $40^{\circ}$ , instead of the temperature of the two being the mean, it will be but  $60^{\circ}$  F.; and if the water be the warmer, it will rise to  $80^{\circ}$  F.; the mean produced by taking two different pounds of water at the same temperatures, being  $70^{\circ}$  F. In the first case, the oil loses 40 degrees and the water gains 20, or the temperature which imparts 40 degrees of heat to oil is only competent to elevate an equal weight of water 20 degrees. By mixing equal weights of different substances at known temperatures with water, and observing the resulting degrees, the specific heats may be determined as referred to water.

The length of time during which substances heated to the same point, cool to a given degree, may also be employed to determine their capacities, for it is obvious that as water takes thirty times as long as quicksilver to become heated, it will take longer to cool. Lavoisier and Laplace determined the capacities of bodies at the same temperature, by measuring the quantity of ice that they would thaw when introduced into a vessel containing it, called the calorimeter.

Water has the highest specific heat of all known substances, and if we take it at 1000, that of alcohol will be 660; sulphuric acid 333; ether 520; mercury 33; iron 114; copper 95; gold 32; glass 179.

These numbers are true only below  $212^{\circ}$  F., the specific heat increasing with the temperature and rarefaction in all classes of bodies.

In the case of gases, air is taken as the standard and made 1 or 1000. By the experiments of Apjohn, the specific heat of oxygen is 808; nitrogen 1048; hydrogen 1459; carbonic acid 1195; vapor of water 3172. But the specific heat is much increased if these gases be heated or rarefied by a diminution of pressure. On the other hand, it is diminished under increased pressures.



Dr. Black, in explaining the phenomena now under consideration, conceived that different substances absorbed unlike quantities of heat, or had different capacities by reason of their porous structure. Such an explanation is not now admissible, but the subject is little understood. There appears to be, however, a close connection between the specific heat of a substance and the chemical power of its atoms. For we find that if the specific heat be made the divisor of a constant number for a similar class of substances, a product is obtained that often represents the chemical equivalent of the body. And again we find that in substances of the same chemical class, the specific heats are in an inverse ratio to the equivalents, or to some multiple of them.

It is in this relation of heat to the weights of the molecules, that we are to search for the cause of the difference of bodies in their capacities for heat, but too little is known of the subject to permit us to enter upon it in an elementary work. It may, however, be proper to remark that the question refers to the amount of heat operating, rather than to its intensity.

#### § 4. LATENT HEAT.

The term latent heat has been introduced into thermotics to signify that, under certain circumstances, the heat applied to a body becomes insensible or latent. Under ordinary circumstances, if we place a substance over a fire, it becomes warm, and the increase of temperature can be measured by the thermometer or by the sense of touch; here the added heat is sensible or free: but if a piece of ice be placed in a vessel over the fire, it does not become heated, but merely thaws, remaining at the same temperature so long as any ice is present. The heat in this case was said by Dr. Black and his followers to become latent or hidden in the produced water. It has also been termed the *heat of fluidity*, because it is occupied in producing a remarkable change from the solid to the fluid state. All solids, in passing into the state of liquids, absorb a portion of heat, but not the same amount in every instance. Liquids, in becoming vapors, likewise render heat latent, and this is termed the *heat of vaporization*, or the "*heat of elasticity*."

On the other hand, whenever the vapor returns to the state of a liquid, or is condensed, this heat reappears; ceasing to be hidden, it returns to the sensible state. So when the fluid becomes solidified, the heat of liquefaction is given out, or becomes manifest or free.

According to the doctrine of Dr. Black and the molecular theory of heat, these phenomena were readily explained, for it

was said that the heat combined chemically with the solid to convert it into a fluid, and was therefore no longer possessed of its ordinary activity; in the same way that caustic potash uniting with vinegar, there is produced a mild saline body having none of the acidity of the potash. It is not a simple thing to explain the disappearance of the heat according to the undulatory theory, but it is to be observed that a result is attained requiring the action of considerable force, that is, the production of a vapor from a fluid, or a liquid from a solid. In these cases, the resulting substance occupies much more space, and the state of its molecules is widely different. To attain these results, the cohesive force of the solid or liquid must be overcome, and, in the case of vapors, nearly destroyed; and we presume that the force termed heat is operating as an antagonist to cohesion, and, therefore, neutralized, and without the power of affecting circumambient matter.\*

The important facts pertaining to this topic will be grouped under three heads: 1st, liquefaction of solids; 2d, ebullition; 3d, vaporization.

† LIQUEFACTION OF SOLIDS.—The form of a liquid depends upon the heat operating on its molecules, or latent in its texture. Hence all fluids possess latent heat; but the amount and the temperature at which they pass from the solid state differ amongst them. Thus mercury liquefies at  $-39^{\circ}$ ; oil of turpentine at  $+14^{\circ}$ ; sulphuric acid  $-47^{\circ}$ ; water  $+32^{\circ}$ ; phosphorus  $+108^{\circ}$ ; sulphur  $+218^{\circ}$ ; silver  $+1872^{\circ}$ ; gold  $+2200^{\circ}$  F. The number of degrees of latent heat necessary to produce the state of fluidity, is not so well known, but has been determined for water at  $142^{\circ}$ ; sulphur  $145^{\circ}$ ; tin  $500^{\circ}$ ; bismuth  $550^{\circ}$ ; zinc  $493^{\circ}$  F. In these cases the degrees of temperature represent the amounts of heat

\* Judging from the phenomena of electricity and light, it is also proper to conceive that the difference between the liquid, solid and vaporous states of matter, may consist in the relations of the sides of the molecules constituting them. Thus, adopting the usual hypothesis that these atoms are spherical, it is customary in electricity and light to conceive that they are endowed with axes, the poles or extremities of which have different properties. Thus when unlike poles are opposite, attraction takes place; when like poles, repulsion. Now we may conceive that the heat rendered latent is a force employed exclusively in effecting the polar states of these atoms, exercising towards them an effect of pressure. And this view is the more plausible, from the fact that the effect ceases if we withdraw the heat, and that an electrical disturbance is always manifest in these cases. According to these remarks, it is inferred that latent heat is not a variety of caloric, but only that agent employed in inducing polarity or a state of pressure, and hence it cannot propagate its usual disturbance beyond the limits of the affected bodies, and also that when the external temperature is removed, the particles return to their former state, the disturbance of the molecules affecting the ether, and setting up the undulations which constitute free, sensible, or manifest caloric.

which would elevate the substances respectively through the measures given. Ice, when becoming water, absorbs  $142^{\circ}$  of heat before it is completely liquefied, and this amount would serve to raise an equal weight of water from  $32^{\circ}$  to  $174^{\circ}$  F. Tin absorbs 500 degrees, or such an amount as would raise that substance, if it were not liquefying,  $500^{\circ}$  F. without reference to its action on water. The distinction will appear, by referring to the subject of special heat, where it will be found that the amount of heat necessary to warm water and other bodies to the same degree, is very different. The heat of liquefaction measured by that of water, is as follows:—Water  $142^{\circ}$ ; sulphur 27.14; bismuth 23.25; zinc 48.3. Hence the latent heat of water is much higher than that of any other known substance.

The temperature at which liquefaction takes place, is a fixed point. The thawing of water is rigorously at  $32^{\circ}$  F., that temperature being maintained during the whole period. But the point of freezing or solidification may be slightly varied under certain circumstances. It has been found that water may be cooled to  $25^{\circ}$  F., if kept perfectly still.

The determination of the heat of fluidity in any substance is effected by taking equal weights of the liquid and the solid, at the point of liquefaction, and observing the action of a similar and steady source of heat. Thus if water and ice at  $32^{\circ}$  F. be taken, it will be found that when the ice is completely thawed, and the resulting liquid at  $32^{\circ}$  F., the water will have reached the temperature of  $174^{\circ}$  F., or have gained  $142^{\circ}$ , which have been rendered latent in the ice. So an equal weight of sulphur at  $218^{\circ}$  F., or the point of liquefaction, remained without alteration of temperature, while fluid sulphur had passed from 218 to  $363^{\circ}$  F., or acquired an increase of 145 degrees; which, therefore, corresponds to the latent heat of fluid sulphur. It may also be determined by mixing the solid and fluid together at different temperatures, and marking the loss of heat.

All liquids, in passing into the state of solids, give out their heat of fluidity. Water in freezing throws out  $142^{\circ}$  F., but this is not suddenly liberated, but produced slowly, for the substance takes a long time to solidify, in consequence of the presence of so much latent heat.

The temperature of northern climates is considerably ameliorated by this property of water, for, on the approach of winter, it is only slowly solidified, throwing out heat in the act. In spring, instead of the frightful inundations which would arise from the instantaneous change of the ice and snow into water, it takes place very gradually, thus regulating the transition from winter to spring which would otherwise be injurious to vegetation.

The preparation of refrigerating mixtures depends upon the

disappearance of heat when solids are suddenly liquefied. Mr. Walker prepared some time since an extensive table, in which are combinations for the purpose of reducing the temperature to— $91^{\circ}$  F.\* Some of these mixtures are useful in the arts and to the surgeon. One part of snow with two parts by weight of salt, produces a reduction of temperature to  $5^{\circ}$  F. Equal parts of nitrate of ammonia and water reduce the temperature from  $50^{\circ}$  to  $4^{\circ}$  F.; this arises from the rapid solution of the salt, and may be used as an application to the skin when ice is not at hand. The solution of sal ammoniac (chloride of ammonium), or common nitre (nitrate of potash), furnishes a sufficient depression of heat to be useful in surgery.

**EBULLITION.**—A fluid urged by heat, at first expands and throws off a considerable amount of vapor, and finally enters into a state of rapid commotion, termed boiling, or ebullition. The disturbance in the fluid arises from the rapid passage of bubbles of vapor through it, the heat being expanded in producing vapor, and no longer warming the fluid.

The boiling point, under ordinary circumstances, is fixed for the same fluid, but is widely different in various liquids. Water boils at  $212^{\circ}$  F.; ether  $96^{\circ}$ ; alcohol  $173^{\circ}$ ; oil of turpentine  $315^{\circ}$ ; mercury  $660^{\circ}$ ; sulphuric acid  $620^{\circ}$ ; whale oil  $630^{\circ}$  F.

It is remarkably subject to disturbance from pressure. For if we place a vessel containing hot water under the air pump, and exhaust the air, its pressure being diminished, the fluid throws off vapor rapidly and appears to boil at temperatures proportional to the rarefaction, and may even boil at  $67^{\circ}$  F. or  $145^{\circ}$  F. below the point at the external pressure of 30 inches of the barometer. This reduction is entirely dependent on the physical impediment presented by the weight of the air; for alcohol placed in vacuo has its boiling temperature also reduced 145 degrees, or from  $173^{\circ}$  F. to  $28^{\circ}$  F.; more volatile fluids flash off into vapor under the same circumstances. As it has been long known that the pressure of the atmosphere diminishes rapidly as we ascend high mountains or in balloons, it became an interesting matter to observe the effect on boiling. It has been found that water boils on the summit of Mont Blanc at  $184^{\circ}$ , and at Quito at  $196^{\circ}$  F., the depression of this point being for small elevations equal to one degree for about 530 feet of elevation. The singular experiment called the culinary paradox, also demonstrates that the boiling point of fluids is remarkably influenced by diminished pressure. It is thus made: a flask of thin glass is one third filled with water and placed over a spirit lamp, until it boils violently,

\* These tables are to be found in the larger treatises on chemistry, or in *Gardner's Medical Dictionary*, article *Freezing mixture*.



so as to fill the upper part of the vessel with steam; it is then well corked. If it be now allowed to stand some time, and then the upper part touched with a cold body so as to condense the vapor of water which fills it, this action will reduce the pressure on the liquid, and throw it into ebullition, although the temperature may be reduced below  $100^{\circ}$  F.

The reverse of this position is equally true. Fluids have their boiling points increased by pressure, but the law of increment is unknown; but it becomes less and less as the pressure rises. Water boils at  $212^{\circ}$  at the ordinary atmospheric pressure; under the pressure of two atmospheres, it boils at  $250^{\circ}$ , under 3 atm.  $275^{\circ}$ ; 4 atm.  $294^{\circ}$ ; 12 atm.  $374^{\circ}$ ; and under 50 atmospheres,  $510^{\circ}$  F. The difference between 1 and 2 being 38 degrees, between 3 and 4 atmospheres but 19 degrees, and between 40 and 50 atmospheres only 24 degrees, or little more than 2 degrees between each atmosphere at this high temperature. As the steam produced is at the pressure to which the water is subjected, it appears that the power of high pressure steam is obtained at a very trifling expense over that necessary to obtain low pressure steam.

**VAPORIZATION.**—Observation teaches us that vapor is rising nearly at all temperatures from fluids, and indeed, in some cases, as ice, from solids also, and that if it were not for the pressure of the atmosphere, most common fluids would be known only as vaporous substances. It has been shown that alcohol would boil at  $28^{\circ}$  F., and water at  $67^{\circ}$  F. without this pressure. But with the ordinary pressure, it is notorious that water evaporates when exposed to the air, even at low temperatures, and a slight deposit of snow often disappears without being converted into water. Hence, evaporation, or slow vaporization takes place in substances susceptible of this change, nearly at all temperatures, but the amount rising as vapor is proportional to the temperature when there is no impediment to the process. Heat is, therefore, as completely the cause of vaporization or evaporation at low temperatures, as of boiling, the difference between these being due to the rapidity of the action and degree of heat, and not to any specific causes.

*The nature of Vapor.*—There being some popular errors on this subject, it may be well to state what are the peculiarities of vapors. This class of substances are aeriform, being perfectly clear and like air, when they are without color. They have not the appearance of a fog, as is commonly supposed. They occupy a very much greater space than the liquid, from which they are derived; thus, at the boiling points, steam occupies 1696 times the bulk of the water, alcohol 519 times, and oil of turpentine 192 times. Vapors differ from gases in returning to the liquid

condition, under the influence of cold and pressure; this is termed their condensation, during which, however, they give out the latent heat they contain.

*Heat is rendered latent in the production of Vapor.*—There is in the case of vapor a molecular state, widely different from that of liquids, and for its production heat must be in every case rendered latent. This is termed the heat of elasticity, from the remarkable elasticity of vapors and aeriform substances. The amount of heat is usually considerable; thus it is found, as compared with vapor of water, at  $1000^{\circ}$ ; that of vapor of alcohol will be  $376^{\circ}$ ; of ether  $163^{\circ}$ ; of oil of turpentine  $138^{\circ}$  F. If the vapor be produced at a point below boiling, the latent heat is greater, being the amount at the boiling point with the difference between it and the observed temperature. In the case of water evaporating at  $60^{\circ}$  F., the latent heat will be  $1000^{\circ}$  F. plus the temperature between  $60^{\circ}$  and  $212$ , or, in all,  $1152$  degrees. There is not, therefore, any gain of heat by evaporating a fluid at a temperature below the boiling point, as was formerly supposed, for all the difference of heat enters the vapor.

The amount of latent heat is ascertained by two means; either by observing the length of time during which a given weight of fluid evaporates away over a constant source of heat; or by measuring the heat given out in the condensation of the vapor of a known amount of fluid, in a weighed quantity of water. In the case of water, if we place one pound over such a fire, that it acquires 25 degrees of heat per minute below the boiling point, it will be found, that at this degree, ( $212^{\circ}$  F.,) it becomes stationary, and that 40 minutes will elapse before it has all evaporated. During this time, it has acquired its former rate of increase, 25 degrees, all of which has been rendered latent. Now the sum of these numbers is 1000 degrees, which therefore represents the heat rendered latent by steam, produced at  $212^{\circ}$  F.

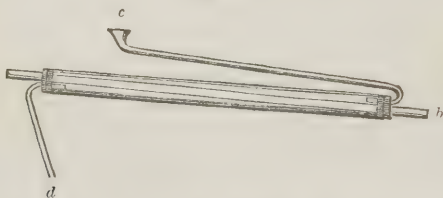
The reverse also holds true, for whenever a vapor passes back into the fluid state, it gives out an amount of heat precisely similar to that necessary to produce the vaporization. In virtue of this fact, vapors exercise a remarkable ameliorating influence on some climates, as on the shores of Newfoundland, and the British Islands. In these cases, the vapors of the gulf stream are condensed on the lands, and giving out their latent heat, warm the air to such an extent, as to elevate the average temperature many degrees. Climates subject to this influence, are not only mild as respects temperature, but are remarkably genial. The condensation of vapor of water is also employed as a means of warming large buildings and conservatories. It is in consequence of the large amounts of heat thrown out in condensation, that we are compelled to resort to various contrivances to liquefy the products



of distillation. In this process, the fluid is placed over the fire in a vessel of glass, earthenware or metal, and vaporized by the access of heat. The vessels employed are termed stills when of large size, retorts or alembics when of smaller dimensions. To the vessel is adjusted a long tube, curved into the figure of a helix, and called the worm of the still for conveying the vapor, and to secure the refrigeration, this is placed in a large vat through which a current of cold water is continually flowing. This contrivance becomes absolutely necessary where the amount of fluid subject to distillation is large, otherwise a portion of the vapor would issue uncondensed.

Liebig has introduced a portable condenser for the laboratory, where the amount of fluid distilled is small. It consists of a cylinder of tin or brass, in the centre of which runs a straight tube *b*, conveying the warm vapor. The cylinder is closed at both ends in all other respects, and when used, is set at a small

Fig. 8.



angle to the horizon. From the lowest end, arises a long funnel *c*, by which water can enter the cylinder, and its position is such, that the warmed portions only flow out, as the escape tube *d* is at the highest part of the condenser. The implement is sustained by a stand, and represented in figure 8.

*Evaporation is a Cooling Process.*—Whenever vapor is produced, heat must be rendered latent, and abstracted from surrounding matter. If there be not a fire or other source of heat, the abstraction of caloric will produce coldness. If the hand be moistened with ether, which is highly volatile, a sensation of coldness will be perceived in the evaporation. This may be also demonstrated by dropping ether upon the bulb of an air thermometer, when the instrument will indicate a considerable fall of temperature.

The cryophorus of Dr. Wollaston, is an instrument designed to illustrate this fact in the freezing of water, by its own evaporation. A little concentrated prussic acid will solidify, if exposed to the air, in consequence of the cold produced by the vaporization of a part.

The cooling effect of evaporation is of considerable influence

in regulating climate. The shores of lakes, and moist countries, especially such as abound in forests, being cooler than sandy and dry countries. Advantage is taken of evaporation by the surgeon, in the treatment of fractures and some wounds, lotions being applied to reduce the temperature of the parts by the coldness they produce. The insensible perspiration of the human body is also intended, for the most part, to reduce the animal heat, for we find that it is much increased during the summer, and is also influenced by the state of the moisture in the air. The human epidermis contains an immense number of minute punctures, being the mouths of the sudoriparous follicles, from which the perspiration arises. It is calculated that a square inch contains 2800 of these, or that there are seven millions over the entire surface. The amount of fluid issuing, varies from  $1\frac{1}{2}$  lb. to upwards of 5 lbs. daily, besides about 18 ounces from the lungs. To vaporize this quantity of fluid at the temperature of the body, requires an immense amount of heat. The function of perspiration is therefore designed by nature to counterbalance the process of calorification, and remove the excess of temperature. Hence we find, that, when in the summer season, the animal heat is rendered excessive by the external temperature, evaporation or insensible perspiration becomes very active, and on the other hand it is reduced in winter. When the air of any district is hot and full of moisture, evaporation from the skin is impeded, and an extreme sensation of heat and oppression arises, which, if not relieved, is a fertile source of disease, and is by some supposed to be the remote cause of bilious and intermittent fevers. Sweat differs from insensible perspiration in being a direct exudation of fluid; its production does not refrigerate the body to the same degree, and it commonly occurs as a result of bodily exertion, or of some cause which impedes evaporation.

The importance of the insensible perspiration to health is scarcely appreciated, and the effect of its diminution in producing disease and death, overlooked. Becquerel and Breschet showed that animals covered with an impermeable coating, speedily died; and M. Mojon has reported a case where a fine child was covered with gold leaf, to make a figure in a pageant, and died in a few hours.

*Circumstances which influence Evaporation.*—Evaporation taking place from liquids or moist solids in the open atmosphere, is subject to several disturbing causes. The amount of water which rises, depends upon the dryness or moisture of the air. The temperature, action of winds and pressure, also influence the rapidity of evaporation.

In air which is calm, and completely saturated with vapor of water, evaporation from this fluid cannot take place. The same

holds for all other vapors in a confined space, but the presence of one vapor to saturation, does not influence the ascent of another of a different kind. It is of considerable importance in meteorology, to know the amount of vapor of water in the air at any time, and for this purpose several instruments have been contrived. Those which merely denote the presence of moisture, are called hygrosopes, those which mark its degree, hygrometers. A sponge moistened with carbonate of potash, a piece of hair or whalebone, serves to indicate the presence of a considerable amount of moisture.

The best hygrometers are constructed on two principles: 1st, that the coldness produced by evaporation increases with its rapidity; and, 2d, that whenever a substance is cooled down to the temperature at which the air is saturated with moisture, a deposition of dew takes place. To the first of these belong the wet bulb hygrometer and the psychrometer, and to the second, Daniell's and Bache's hygrometers. But it is not necessary that the student should resort to these for the determination of the dew point, as it can be reached with great expedition, by means of a little ice, a tumbler of water, and a thermometer. A small tumbler or wine glass of thin material and dry exterior is selected, and three quarters filled with water; into this a few pieces of ice (or nitre), are placed, and the whole stirred with the thermometer, the temperature of which is marked at the moment of the first deposition of a dewy mist on the exterior of the glass. This is the *dew point*, or temperature at which the air is full of moisture, and its capacity to receive more vapor, or *drying power*, is the number of degrees between this point and the atmospheric temperature. When the temperature of the air is  $70^{\circ}$  F., and the dew point  $50^{\circ}$  F., the drying power will be  $20^{\circ}$  F., and vapor will rise freely. As the dew point approximates to the atmospheric temperature, the rate of evaporation becomes less, and is finally arrested when they are the same, as this indicates that the air is saturated with moisture. Under such circumstances, especially in the summer, the insensible perspiration of the body becomes nearly arrested, and a sensation of oppressive heat and languor arises.

The probability of rain is also connected with this condition, for when the air is saturated with moisture, a cold wind will condense it, and thus produce a rain storm, whereas this result could not take place if the air were altogether dry. The hygro-metric state of the atmosphere is also seen in its effects on plants, which appear succulent, and full of vigor in a moist air, but withered when the drying power is great.

Winds, or air in motion, influence evaporation mechanically by presenting new portions of matter to the fluid, and thus hindering saturation. According to the observations of Dalton, a

brisk wind increases the amount of evaporation from one-third to one-half. It is in consequence of this effect that wind is so eminently refrigerating on the human body, the insensible perspiration being considerably increased by its action, the coldness of the surface is rendered greater. The increased evaporation is also apparent in the rapid drying of linen in windy weather.

The amount of vapor which can exist in any bulk of air or gas, depends, however, primarily upon the temperature. The drying power and the action of winds influence the rate of evaporation, but do not affect the amount which any volume of air or space can contain. This depends upon the temperature of the space, and is the same whether it be a vacuum, or filled with gases or other vapors. It is found that 100 cubic inches at  $32^{\circ}$  F., will contain only .136 grain of vapor of water; at  $60^{\circ}$ , this rises to .338 grain, and at  $100^{\circ}$  F., to 1.113 grains. From these numbers it will be seen that the amount does not only depend upon the temperature, but that the proportion of vapor rises rapidly with the heat, there being not simply double the amount at  $60^{\circ}$  as compared with  $32^{\circ}$ , but an excess, so at 100 there is more than three times the quantity at  $60^{\circ}$ , although the increase of heat is not double. It is found that, as the temperature rises, the weight of vapor increases in a much higher ratio, so that whilst there is but 1.113 grains in a vacuum over water at  $100^{\circ}$  F., there will be 14.962 grains at  $212^{\circ}$  F., at little more than double the temperature.

*The elasticity of Vapor.*—It has been seen that heat tends to increase the amount of vapor in any space, but each addition is, under ordinary circumstances, opposed by the air or other matters present, and has to overcome this resistance. In a vacuum, vapor forms immediately, but in a volume of air, it has to act by its elastic force, in dilating the gas to find admission; hence in this case the rise of vapor is impeded. Every accession of vapor enlarges a volume of air, and pushes out a portion, the amount increasing with the temperature. The force exerted by the vapor is termed its elastic force, and it is measured by its power to depress the column of mercury in the barometer.

It is well known that the pressure of the atmosphere is capable of supporting a column of mercury of 30 inches, (see *Atmospheric Air*;) but if we introduce a few drops of water, alcohol, ether, or any other vaporizable substance into the barometer tube, the mercury will be depressed, and no longer stand at 30 inches. The depression arises from the pushing action, or elastic force of the vapor, and increases rapidly with the temperature. If water be introduced above the mercury, at various temperatures, or if heat be applied by means of a hot ring of metal around the barometer tube at the place where the water floats, we find



that the mercury descends with each addition of heat, its elastic force, or tension increasing with great rapidity. It has been determined by Dr. Dalton that the elastic force of vapor of water is as follows :—

Temperature.	Elastic force in depressing the mercurial column.
32° F. - - -	0.200 of an inch.
40° " - - -	0.263 "
60° " - - -	0.524 "
80° " - - -	1.000 inch.
100° " - - -	1.860 "
120° " - - -	3.330 "
150° " - - -	7.420 "
180° " - - -	15.150 "
200° " - - -	23.640 "
212° " - - -	30.000 "

From this we learn that the elasticity or tension rises far more rapidly than the temperature, being but 1.86 inch at 100° F., and 30 inches at 212° F., or the boiling point of water. In all other fluids the tension is equal to 30 inches at their boiling points, the phenomena of rapid vaporization depending upon the force with which the vapor is produced. At the boiling point, the elasticity of vapors is equal to the pressure of the atmosphere, and resistance to their formation ceases. This table also puts us in possession of the reason why the weight of vapor of water in the air rises so rapidly with the temperature, for as the elasticity increases, the impediment offered by the air diminishes, and the amount of vapor rising is enlarged. The amount is always proportional to the elasticity, and the latter is as the heat.

The elastic force of vapors differs with their volatility; those fluids which have the lowest boiling points, produce the most elastic vapors. Thus, if we introduce ether, water, and alcohol into three barometer tubes at the temperature of 80° F., the water will depress the column 1 inch, the alcohol 1.9 inch, and the ether 20 inches. These numbers 1, 1.9, and 20, therefore, respectively represent their elasticities at the temperature of 80° F.

*Maximum Density.*—The amount of vapor capable of existing in any space, at a given temperature, is fixed, and cannot be exceeded. The term *maximum density* is employed to signify that this saturation has been reached. If any more vapor is driven into such a place, it does not become diffused into every part, but is condensed on the sides of the vessel, or on the coolest points. On the other hand, the slightest diminution of temperature, or increase in pressure causes a precipitation of some of the vapor; and dew or rain is produced if the operation takes place on a large scale. So, when a cold wind invades a part of the atmosphere saturated with water, or in which the vapor has a maximum density, a portion is precipitated, and a cloud is formed



if it occur in the higher regions of the atmosphere, or a fog if on the surface of the earth. Reducing the pressure of a volume of air saturated with moisture, produces a mist, in consequence of the demand for heat created by the dilatation of the air; for it will be remembered that the specific heat of gases increases with their rarefaction. The nephelescope is an instrument designed to show the production of clouds by the diminution of pressure. It consists of an air pump receiver connected by means of a stop-cock, with a large globe of glass, which is situated superiorly. The globe contains air saturated with vapor of water. The communication between the vessels being closed, the air of the lower is removed by the air pump, and then the communication is re-established. By this means, the moist air of the globe is suddenly dilated, the rarefied air withdraws heat from the glass and vapor, and the point of maximum density being lowered by diminished temperature, a portion of the vapor becomes visible, and forms a cloud. In nature, clouds often result from the same operation—as when a volume of warm moist air is transported by winds into the elevated regions of the atmosphere, where the pressure being less, the air expands, and vapor is condensed as in the instrument.

*The action of Pressure on Vapors.*—The point in which vapors differ from gases, is the ready condensation they suffer from the application of pressure or cold. In a space saturated with vapor, the slightest increase of pressure produces liquefaction, and the liberation of the latent heat. In the case of gases, the latent heat is also liberated by pressure, but the degree necessary to bring about liquefaction is considerable, and sometimes altogether beyond our means, as in oxygen, hydrogen, nitrogen. The evolution of heat, by the condensation of gases, may be experimentally shown by the fire syringe. This consists of a cylinder of brass, closed at one end, in which fits a tight piston, the lower end of which contains a cavity for the accommodation of a little tinder or punk. If the piston be driven down sharply, so as to condense the air of the cylinder, with considerable force, the heat evolved will ignite the tinder. But there are gases which are condensible under pressure, as was shown by Mr. Faraday. It appears from his researches, that

Sulphurous acid gas	is condensed by a pressure of 2 atmospheres at	45° F.
Sulphuretted hydrogen	" " 17 "	50° "
Carbonic acid	" " 36 "	32° "
Chlorine	" " 4 "	60° "
Nitrous oxide	" " 50 "	45° "
Cyanogen	" " 3.6 "	45° "
Ammonia	" " 6.5 "	50° "
Hydrochloric acid gas	" " 40 "	50° "

As pressure is capable of condensing these gases, cold will produce the same result if sufficiently severe, but the degree is not in most cases at our command. It has been calculated that gaseous ammonia requires a temperature of  $-63.4^{\circ}$  for condensation, whereas carbonic acid requires  $-230.8^{\circ}$ , and nitrous oxide  $-252.4^{\circ}$  degrees.

A vapor separated from the fluid whence it rises, cannot resist the slightest pressure, but if the heat be continued, and fresh supplies of matter rise, a powerful concentration may be reached. This is termed cumulative pressure from the contained additions of vapor. The pressure of vapors under these circumstances, rises with great rapidity, because the latent heat of such concentrated vapor does not increase but diminish. If to a stout metallic vessel containing water, heat be applied until the whole is  $212^{\circ}$  F., the vapor or steam will be found capable of sustaining the pressure of the atmosphere, as measured by 30 inches of mercury, or 14.6 pounds on the square inch. This vessel, heated to  $250^{\circ}$  F., that is, only 28 degrees more, generates steam of double the pressure, such that it is capable of counterbalancing 60 inches of mercury, or 29.2 lbs. on the square inch. At  $294^{\circ}$  F., the steam has a pressure of 4 atmospheres, or 58.4 lbs.; at  $359^{\circ}$  F. it equals 10 atmospheres, or 146 lbs. on the square inch.

Thus by the application of heat to a fluid, in a confined and strong vessel, the vapor acquires immense elastic force, overcoming after a time the most powerful resistance. The high pressure engine is made on this principle. The steam is generated in a strong boiler, and not allowed to pass into the cylinder until under a pressure of four or more atmospheres; it now exerts immense force, and drives machinery which steam at the ordinary pressure could not move, but as experience proves, it is often a source of serious accidents. In these engines the steam is allowed to escape from the cylinder into the air, but in the low pressure, or common engine, it is conducted into a tank of cold water, and reduced back into the state of water, by condensation.

If, on the other hand, a vapor be separated from its source, and heat is applied, it enlarges its dimensions and increases in elasticity, but not to the extent pointed out above. The elastic force or pressure is only moderate even at high temperatures. In this action of heat on insulated vapors, they are completely identified with gases, the same law expressing the increase of dimensions in both cases. If we take a cubic inch of any vapor, and of air, place them under similar circumstances, and apply the same heat, they will dilate equally, and acquire elasticity in the same degree. The diminution of pressure is also attended with the same results in both cases, the law of Marriotte being applicable to vapors as well as gases. The law is as follows:—*The volume of a gas is*

*inversely as the pressure.* If we double the pressure on a gas, its volume is diminished one-half, and if, on the other hand, we decrease the pressure one-half, the volume is doubled. Vapors cannot be condensed by pressure without liquefaction, but they dilate according to this law. Hence, diminished atmospheric pressure is conducive to the rapid production of vapor.

Cold condenses vapors by removing the heat necessary to impart to them their peculiar structure, and the degree necessary for this purpose depends upon the amount of latent heat in the particular body. No application of cold can liquefy oxygen gas, for its latent heat is considered very high, and its elastic force great; but in the case of ordinary vapors, the degree of cold is not remarkable.

## § 6. SOURCES AND EFFECTS OF HEAT.

The great source of heat as respects the earth, is the sun, but electrical, chemical, and mechanical actions, tend to develop heat radiations. The earth has also been regarded as a mass whose temperature influences a variety of operations on its surface, but from the extreme coldness of those parts where the sun is absent for a considerable period, its temperature can scarcely be supposed to exert any remarkable influence. It is, moreover, apparent, according to the law of the equilibrium of temperatures, that if the earth's surface were in those portions in which the sun is absent, warmer than space, rapid radiation would take place, tending to reduce the excess of heat in a short time. The temperature of the Arctic regions, measured by navigators, is about  $-58^{\circ}$  F., and this agrees with the temperature of space deduced by Baron Fourier from other considerations. This equilibrium has been stationary for a long time, for we have records of the rate of the diurnal revolutions of the earth for upwards of 2000 years, during which there has been no alteration. If the earth had cooled during this time, its volume would have contracted, and the revolution have become more rapid, and as a consequence, the length of the day shorter. But whilst the crust of the earth has no available degree of heat, the action of the sun makes itself felt to such an extent as to render existence possible. It is known that neither animals nor plants can live below  $32^{\circ}$  F., or above  $212^{\circ}$  F., the freezing and boiling points of water, and, in truth, the limits are much more confined. The surface of the earth at  $-58^{\circ}$  F., can sustain no organized being, but the heat of the sun acting unequally, produces the varieties of climate, and is an important cause of the variations in animal and vegetable existence. Over the tropics, where the rays pass almost perpendicularly, and

through the least interval of air, their power is most felt; they not only heat the surface, but penetrate the soil, by conduction, to a considerable depth, constituting these portions of the earth a store-house of heat. In northern positions, the rays arrive obliquely; they are dispersed and fall on a curved surface, the same amount being distributed over a much larger space than in the tropics; a greater amount of absorption also occurs in their passage through the increased thickness of the atmosphere; they are, therefore, enfeebled, and neither raise the temperature of the surface, nor penetrate the soil in the same degree. Hence, during winter, the earth freezes, and as we proceed towards the poles, this takes place to increasing depths. The variable inclination of the sun's rays in summer and winter, and the period during which he continues above the horizon, constitute the principal causes of the diversity in the temperature between these periods. The air is likewise unequally affected in different parts of the world; over the tropics it is heated by convection to a great height, the point of perpetual snow or congelation being raised to 15,000 feet, whilst at  $40^{\circ}$  of N. latitude, it is 9000; at  $75^{\circ}$  of N. latitude, it is 1000, and at  $85^{\circ}$  N. latitude, but 117 feet from the earth. If we trace a line through these points, it will represent a curve rising gradually from the surface at the pole, to the equator; below which, the temperature is greater than  $32^{\circ}$ , as an average for the year; above, it is colder. The curve of perpetual congelation will be similar in the southern hemisphere. Observing the relation between temperature and moisture, it will be apparent, that, under ordinary circumstances, as the atmosphere over a warm latitude contains more moisture than over a cold situation, the rains will be heavier, and of longer duration. Other meteorological phenomena will also be regulated chiefly by the temperature of this portion of air. If we pass below the earth's surface, we find that in situations where the sun's action is greatest, the temperature will be affected to a considerable depth. If we dig downwards at the equator, the earth is found to become cooler as we proceed, until a point is reached where the temperature is fixed; beyond this the heat rises again. The temperature below the fixed point, or the stratum of invariable temperature, is due to the heat of the earth.

If we examine the temperature at any medium latitude, we find the same phenomena; the upper crust gradually diminishes in temperature to a certain depth, depending on the location, and beyond this there is an increase. At the latitude of Philadelphia, the depth to be attained before we reach the stratum of fixed temperature, will be about 40 feet; below this the temperature rises at the rate of about one degree Fahrenheit for every additional



42 feet of descent. So far as observations have been made, the increase seems to be nearly uniform. On these grounds it appears, that if we penetrate a mile, the difference will be  $120^{\circ}$  F.; at the depth of two miles, water cannot exist, being converted into steam; at four miles tin will melt, and at thirty miles depth, iron and most rocks will be in a state of fusion. This deduction, together with the phenomena of volcanoes, constitutes two of the principal grounds of the igneous theory of the earth. It is supposed that, in the commencement of time, this globe was in an incandescent state, and that it has cooled down on the surface to a state of equilibrium, but is still occupied interiorly by matter at an intense temperature. The depth of thirty miles is almost as nothing to the radius of the earth; hence the cooled crust is merely a pellicle on the exterior, but of such poor conducting power as to separate us from the central fire. However this may be, the temperature of the globe, on its surface, is now so far reduced, as to furnish no available supply of heat for the maintenance of life.

Artificial heat, such as that of the fire, is the product of chemical action. Indeed, with the exception of a few unimportant instances of the production of heat by friction and electricity, this agent appears to be in nearly every case set in motion by chemical action. We find that, as the furnace is urged, the heat increases, being in all cases proportional to the combustion of fuel. This is a chemical process in which the fuel becomes combined with a constituent of the atmosphere (oxygen), to form regular chemical products.

The animal heat was formerly supposed to have a source *sui generis*, but it is now understood to arise from a slow chemical change analogous to that taking place in combustion. The arterialized blood containing free oxygen gas, is constantly acting on the tissues of the body, and especially the fat, and producing by this union carbonic acid and water, the former of which is found in venous blood, and is thrown out by the lungs. These are also the products of combustion in the fire-place, whenever fatty matters, or bodies containing the same elements as fat, are consumed.

*Effects of Heat.*—The principal effects of heat on inanimate matter have been detailed—the expansion of bodies; its relation to the forms of matter, whether they be solid, fluid or gaseous, and its tendency to attain an equilibrium. Its influence over chemical operations will be pointed out at length in the course of the work. This force has, however, several important effects on animated objects which it is proper to mention in this place. The chief of these may be considered under the following heads:



1. The Relation of heat to climate.
2. The Relation of heat to animals and plants.
3. The Relation of heat and cold to man.
4. Heat and cold as therapeutic agents.

1. *The Relation of Heat to Climate.*—Temperature constitutes the principal, but not the only element of climate. It has already been explained that the difference in intensity of the sun's rays, falling at different latitudes, is chiefly due to their obliquity and the curve of the earth's surface. If heat were the only element, all places on the same latitude would have the same average climate, but such is known not to be the case. Humboldt has determined that if a line be traced on a map, through those places which have the same average temperature during the year, it constitutes a curve altogether different from the line of latitude. The line of  $32^{\circ}$  F. passes in Europe near Ulea in Lapland at  $66^{\circ}$  N. lat., but descends in crossing the Atlantic to  $54^{\circ}$  N. lat. in Labrador, or 12 degrees south; it then rises in passing through the American continent, reaching its highest point on the western coast, descending again to the eastern shore of Asia, and rising to the west of Europe. This constitutes a double curve, the two highest points of which are on the western coasts of America and Europe, and the lowest points on the eastern shores of America and Asia. To this curve the name of the *isothermal line* has been given. The isothermal lines of  $41^{\circ}$ ,  $50^{\circ}$ , and  $59^{\circ}$  F., obey the same general outline, but they do not fall so low on the American coast. Thus the line of  $41^{\circ}$  F. is found in Stockholm, lat.  $59\frac{1}{2}$  N., and Newfoundland, lat. 48 N., the fall being  $11\frac{1}{2}$  degrees. The line of  $59^{\circ}$  F. passes near Rome and Florence, lat.  $43^{\circ}$  N., and reaches Raleigh, N. C., lat.  $36^{\circ}$  N., making a descent of but seven degrees. As the temperatures become higher, the curves correspond to the lower lines of latitude. These lines represent the average temperature, but give no information of the difference of heat between summer and winter. On this point there is less opportunity for reaching a useful generalization, for local disturbances operate more completely. It is, however, established that the variation increases as we ascend the continent from the gulf, the deviation being less in Florida and the West Indies than in northern latitudes, and becoming greater as we pass through the middle to the northern states, and into Canada. Thus the difference between the hottest and coldest months at Tampa bay, is  $22^{\circ}$  F., at New York  $55^{\circ}$  F., at Quebec  $60^{\circ}$  F.

It is not for us to enter upon the causes which produce the wide diversity in climate between western Europe and the United States, but it may be well to point out to the attention of the student, the influence of prevailing winds, the action of warm vapors

such as those of the Gulf Stream, the neighborhood of extensive forests or high mountains, all of which exert an important influence. Forests attract moisture, or condense the vapor of the air to a considerable extent; they also impede the escape of moisture by shading the earth; hence wooded countries are well watered, and their temperature is reduced. Indeed, many portions of the earth have been converted into deserts by the destruction of their forests.

To the physician, a knowledge of climate is of considerable importance in the treatment of disease. It is necessary he should discriminate between a dry hot climate, a moist hot climate, an equable climate, and a bracing equable climate. To the consumptive an equable moist and warm climate is useful, a dry hot climate would be injurious. Such find great relief at Pensacola, in Florida, and in any other situation on Tampa Bay; where the heat of summer is not much greater than in Philadelphia, being  $80^{\circ}$  F., and the temperature of winter seldom falls below  $58^{\circ}$  F., whereas in Philadelphia, it reaches  $30^{\circ}$  F. Madeira, in the island of Funchal, is another excellent situation; here the temperature of winter is  $60^{\circ}$  F. and that of summer  $82^{\circ}$ , the seasons flowing into one another, so as to produce a remarkable uniformity of climate. To either of these places the consumptive may be sent in the *early stages* of the disease, as well as patients laboring under chronic rheumatism and bronchitis. The West Indian islands are too enervating to most persons; the eastern coast of Florida is often recommended, but the severe winds here are very objectionable. There is, however, great advantage to be derived from the amusement of the mind, and for this reason certain places in Europe are frequently selected, as Rome; Florence; Pisa; Undercliff in the Isle of Wight; Torbay in Devonshire, England; where the delights of society can be had as well as a genial climate. Asthma and scrofulous diseases are often much benefited by change of climate. Dyspepsia, hypochondriasis, and the cachexies, often give way to the excitement of travelling, and are especially benefited by a sea voyage. It is to be observed, that the great heat of a tropical climate is seldom useful, and often injurious; it is calculated to develop cerebral and hepatic disease, if there be any tendency to them, and by the great excitement experienced, often shortens the days of the patient laboring under advanced consumption. Exercise is also impeded in such situations, and this is one of the chief curative means. It has been recommended that patients spending a winter in Pensacola, should travel northwards in the summer, so as to add the excitement of a journey, and the pleasures of society in the watering-places, to the benefit of residing in a genial climate.

2. *The Relations of Heat to Animals and Plants.*—The relations of heat to organized objects are numerous, existence being impossible except between a narrow range of temperature. The plants allied to the red snow (*protococcus nivalis*) are the only living things which can exist at  $32^{\circ}$  F., and very few are found at a temperature of  $120^{\circ}$  F., except minute algæ; one of which exists in boiling water, the *ulva thermalis*. The capacity to manifest the phenomena of life, in the higher animals, ceases far below the boiling point of water, for the disorganization of scalding is produced at that temperature. No vegetable product can exist beyond a red heat, all being decomposed at that temperature.

The temperatures most conducive to animal and vegetable existence are from  $50^{\circ}$  to  $110^{\circ}$ ; beyond, in either direction, the operations of existence become impeded. In the larger animals, there is an internal source of heat, which enables them to enjoy a wider range of climate; but even with this provision, the species rapidly change as we approach the limits of the temperate zone. We observe in the north a great development of hair or fur on the skin, to preserve, by its non-conducting power, the animal heat. On the contrary, in the tropics we discover dogs without hair, and find that the wool of the sheep degenerates into a sparse covering of hair. The range of temperature in which given animals can flourish, is for the most part very limited. The effect of hybernation, and the torpid state in which reptiles pass the hot dry season, are also in a measure attributable to the action of temperature.

In the vegetable kingdom, the influence of heat is remarkably apparent. In the arctic region, plants scarcely exist. The first objects which the eye encounters are lichens, and dwarf shrubs; the willows, birches and pines succeed these. In a lower portion of the temperate zone, are found the oaks, elm, and forest trees, with the grain plants, and in the lowest limit of this region are the orange, myrtle, olive and vine, yielding rich stores to the cultivator. In the tropics, the vegetable world acquires all its luxuriance; the palm trees, the mahogany and teak, furnish the most graceful and splendid objects of this class. Here the resin-bearing plants, the dye-woods and flowering trees acquire a full developement. But in these results the action of light is also powerful.

The migrations of birds and fishes are also connected with changes in the seasons. As the winter approaches, the duck and woodcock desert the lakes and woods of the north, to enjoy a more genial climate, and return again with the spring.

3. *The Relations of Heat and Cold to Man.*—In consequence of the ability man possesses of dissipating the cold of extreme northern positions by artificial heat, his range of habitation is

much greater than that of other creatures. But whilst this power gives him possession of the globe, it is attended with many injurious effects on his health and developement. In the arctic, we find the Esquimaux, Laplanders and Samiodes, scarcely human, living in holes in the ground, with hardly a glimmering of intellect. In the other extreme, we find him oppressed by heat, reduced in longevity, slothful, almost inane. Such are the rewards of the enterprise which distributes our race from the pole to the equator. We do violence to the laws of heat. Many of our diseases depend on climate; witness consumption, leprosy, elephantiasis, frambæsia, and the hepatic affections of warm regions. Excess of heat or cold continually undermines the system. In the former case, the circulation is fuller, the tissues are rendered lax by dilatation, and man instinctively seeks rest to avoid the distressing heat, and a state of partial congestion occurs in every part of his frame. The brain is enfeebled, the liver gorged, and the system enervated. Slight excesses bring on fatal diseases, in which the recuperative powers of the body are of little avail. Not only are the diseases of hot countries peculiar, but the treatment must also be modified to guard against the enervated state of the patient. The remedial means which would be necessary in the north, if applied to an inhabitant of the tropics, would be altogether improper. Such persons are too much enfeebled by general bleeding, and are to be treated on the anodyne and refrigerant plan, rather than by active depletion. Where the climate is excessively cold, the vital powers are equally depressed, and it is only by severe exercise that the inhabitants are saved from a species of hybernation in the winter, which would extinguish life. Cold acts by depressing the chemical changes in the body essential to existence, and actually reducing the degree of life. During a state of vigor, it is only by the consumption of immense quantities of fat and oily matters, that these people are able to resist exterior cold by the animal heat. They are dwarfish, feeble, and short lived.

The true habitat of our race is the southern portion of the temperate zone, where the variations of temperature scarcely call for change of raiment, and where, under a natural condition of things, everything would appear to minister to temporal happiness and longevity.

4. *Heat and Cold as Therapeutic Agents.*—That heat and cold should possess extraordinary medicinal powers, will appear, if we consider that the chemical actions of the body, in which we include the cause of the circulation of the blood, are increased by heat and diminished by cold. Under the influence of heat, the circulation becomes fuller, the blood passing freely into the capillaries of the skin; as a consequence, perspiration and the secre-



tions are increased, and the whole body is thrown into a state resembling that of fever. If the heat be dry, as that of summer, or of a stove, an abundance of perspiration transudes; if it be moist, as in a vapor bath, ( $120^{\circ}$  F.,) sweat is formed, and the tissues acquire a degree of relaxation that assures us of the diversion of a large excess of blood to the skin.

In these two states, heat exercises a very different action, being, when dry, stimulating, and attended with less oppression than when applied as vapor or the hot bath, ( $110^{\circ}$  F.) In the latter cases, it is enervating; the activity produced in the functions of the body by these means affect every part, the head, the liver, the intestines, and is followed by a subsequent reduction of action, feebleness and sleep. The hot-bath also differs from the vapor-bath, as regards the function of perspiration, there being little sweat in a bath of  $100^{\circ}$  F., whereas in the vapor-bath, there is a large amount. If the object be to subdue irregular action over the skin, the vapor-bath is most effectual, but it is more debilitating. Heat, either in the dry state, or as hot water applied locally to the skin, produces a rubefacient, or derivative action, according to its degree. This is often of great service in relieving the lungs or abdominal viscera from irritation, and is applied by means of a poultice, the materials of which, usually corn meal, or linseed meal, retain the heat a long time. Sir A. Carlisle recommended the application of a piece of metal heated by immersion in boiling water to the skin, as a substitute for blistering. The action is the same, the pain is said to be less, and there is no apprehension of strangury.

Boiling water produces a partial disorganization of the tissues: it coagulates the albumen of the membranes, destroying its functions, and the parts so injured are thrown off by the processes of nature. In treating such accidents, the principal indications appear to be the exclusion of air and the adoption of means to hinder contractions by the irregular deposition of the new portions of matter. To exclude air, a soap of linseed oil and lime-water seems to be the best application. Scalds which injure vital organs, or destroy an extensive surface, are necessarily more serious, but the chemical effect is the same in all cases. Burns differ from scalds in the separation of a large amount of the fluid portions of the tissue, as well as the coagulation or destruction of the albumen and animal matters. The actual cautery owes all its power to these chemical effects; it suddenly dissipates the water of the tissue, which amounts to nine-tenths, and converts the animal matter into a hard solid, capable of obstructing the flow of blood. The hot-bath and other means of employing heat, are contra-indicated in general febrile affections, plethora, aneurisms, or hyper-



trophies of the heart, nervous excitability with feebleness, and in every case where it is improper to increase the circulation.

Cold acts in a manner precisely the reverse of heat. It drives the circulation from the part, constringing the vessels and diminishing chemical action, in which we also include the cause of the capillary circulation. It is therefore operative in directing the blood to the organs of the interior, as well as subduing the circulation. Applied generally, by exposure to a cold air, or to the cold water bath (45° F.), it contracts the skin, and produces a sense of oppression internally. If this be continued for a considerable time, the circulation becomes so slow that the entire body is chilled, venous congestions occur in the head, chylopoietic viscera and lungs, and death from want of the aeration of the blood, ensues. But when the action is for a short time only, the capillaries of the skin alone are affected, and upon the withdrawal of the agent, the circulation being re-established in these parts, a glowing sensation of heat, or reaction, occurs. Cold water, applied locally and suddenly, produces a sharp action on the capillaries of the parts, communicating a sensation to the nervous centres that usually produces spasmodic actions. It is on the nervous centres that cold is most influential as a therapeutic agent. Cold, applied by means of pounded ice, in bladders, to the head, so completely subdues the capillary circulation of the brain, as to arrest incipient inflammation, and if continued sufficiently long, destroys the attack. Dashes of cold water, and the cold water shower bath, are equally efficacious in insanity and chronic irritation of the brain. But the application of cold is injurious over the chest or stomach, in inflammatory affections of the contained organs. The amount of blood circulating in these parts, and the remoteness from the source of cold of many organs, render it impossible to impress every part with this agent. Whilst circulation is diminished on the skin and layers of muscles, it is rendered more active in the deeper seated and affected organs, from the increased quantity of blood diverted to them. In these cases, the derivative action of hot fomentations and poultices is required, and is beneficial.

In the treatment of serious accidents, as compound fractures of the limbs, and in averting inflammatory action after wounds, severe burns and operations, cold water is the most valuable agent we possess. Applied by irrigation, so that a small stream flows over the part continually for several days, it subdues every approach to inflammatory action, whilst it does not hinder the healthy processes of restoration, if the temperature be mild.

As a *morbific agent*, cold is of the highest consequence. It is not to be anticipated, that, whilst such remarkable effects arise from its proper application to the healthy body, it is without

injurious consequences when long continued. Exposure to cold or draughts of air, by disturbing the circulation locally, produces rheumatisms, catarrhs, and neuralgic affections. Wet feet, by which we mean cold and wet feet, are a prolific source of inflammatory disturbances, by arresting the capillary circulation of the part. So if the continued action of cold be on the chest, abdomen, or head, inflammatory actions, which may be local, or affect the entire system, arise. The chilly dews of the autumn, following days of heat, are recognized by some practitioners as the causes of autumnal diarrhœa, bilious and intermittent fever. It is certainly true, that these affections fall mostly upon those exposed to the dews, but it appears that, independently of this, a specific malaria is also necessary to produce some of these diseases.

## LIGHT.

*The Nature of Light.*—Light, like heat, is now generally thought to be an effect produced by the vibrations of the universal ether. The waves so originating, are propagated with immense velocity, and act upon matter in various ways. Some pass through the structure of bodies by radiation, being bent or refracted in their course; others are reflected, and some are absorbed. This agent is not known to increase the dimensions of bodies like heat, but it is capable of producing numerous molecular changes of a chemical nature. A few substances have the property of absorbing the rays of light, and subsequently emitting them when acted on by chemical, electrical, or other agents. Such are the phosphorescent substances, of which fluor spar, oyster shells calcined with sulphur, and fused nitrate of lime, are instances.

Its intimate connection with heat has been already pointed out; both agents arising simultaneously in the process of combustion, and heat being in nearly every case associated in nature with light. The moon's light, and the phosphorescence of some insects, appear to be nearly without heat. The rapidity of propagation, 195,000 miles per second, is the same, and the diminution of brilliancy follows the same law, being inversely as the squares of the distances. These agents differ, however, in their relations to matter, possessing very different actions on chemical substances, light decomposing many which heat cannot affect, and the reverse. In no instance is this more apparent than on the tissues of the body, heat being perceived nearly in every part, whilst light can only influence the retina. Hence, although they be forces, and closely allied, it is customary to separate them in description, and consider them as two agents from the different relations they possess to matter. Light is of much less importance in general chemistry than heat, but in organic chemistry it is the active agent, producing the compounds of the plant which are necessary to its developement, and the sustenance of animals. This subject belongs, however, more to physics than chemistry, and we shall introduce only so much as may be necessary to explain its general properties.

*Of Radiant Light.*—Light advances in great spherical waves, but any portion striking on a limited surface may be considered a ray, the path of which, from the luminous source, has been a straight line. The ray falling on a hard polished surface, will be

reflected or thrown off according to the same law as the ray of heat, the angle of incidence being equal to the angle of reflection. If the reflecting surface, whether a mirror, or polished metal, be curved, the same effects will ensue as in heat. The concave surface will throw the rays together, causing them to meet in a point, distinguished by its brightness, and called the luminous focus. On the other hand, a convex mirror disperses the light, forming no true focus. But as the rays of light usually reach the eye after having been reflected from objects, they generally communicate an impression of figure and color, called the image. Except light be directly derived from the sun, it always falls on the eye associated with a picture or image, which is produced by the unequal reflecting power of objects, and their relations to color. Hence, although the convex mirror cannot condense light, it yields an image;—the difference between these reflecting surfaces being, that the concave mirror furnishes a magnified representation, and the convex a minified image. The plane mirror neither enlarges nor diminishes the size of the object.

The principle of reflection is employed in medicine, in the catoptric examination of the eye, and the use of the speculum. The *catoptric examination of the eye* is practised for the detection of cataract, the process being as follows. The iris is dilated by extract of belladonna, and the patient being in a dark room, a lighted candle is held before the pupil, and the images formed by reflection observed. If the eye be sound, or amaurotic, there may be seen three small images of the candle flame, one formed by reflection from the cornea, another, much feebler, from the anterior surface of the crystalline lens, and the third, which is very feeble, from the posterior surface of the lens. In cataract, both the latter images may be absent, and the innermost will certainly be destroyed by the opacity of the crystalline. It is, therefore, a capital means of diagnosis between amaurosis and cataract.

The *speculum* is a conoidal tube of steel, the inner surface of which is highly polished; it is furnished with a handle for facility of introduction. There are various kinds, some being made with a tube of one piece, and others of two or three, so that they may be more readily introduced and expanded afterwards by a screw, or other contrivance. They are employed in the examination of the natural cavities of the body, as the meatus auditorius, the vagina and rectum. When these instruments are to be used, the patient is placed in a convenient position, in a dark room, and the speculum being introduced and dilated, the operator holds a lighted candle in the axis of the instrument, and directing his eye to the polished sides of the tube, adjusts the light and speculum, until he sees a reflected image in the polished metal of such parts of the cavities as he wishes to observe. It may be necessary, especially, in examining the rectum, to observe the tube inch by

inch, as we withdraw the instrument. The speculum has been of great service in determining the diseases of the neck of the womb, especially in those cases of protracted leucorrhœa which were formerly considered incurable. It will be perceived that the metal acts as a simple mirror, and the nearer its sides approach to planes, the more natural is the image of the parts, the curved tube distorting them very considerably.

*Refraction.*—When the rays fall on a transparent medium, they are more or less transmitted. If we examine the course of the rays, they are found to be bent out of their direction by this passage, and are said to be *refracted*. All transparent substances refract light, but the degree of refraction depends upon the substance, and upon the obliquity of the rays. The refracting action of water is readily perceived by holding a rod in this fluid, somewhat inclined to its surface; at the point where it touches the water, the rod will appear bent, the immersed portion taking a direction different from the true position of the object. Another fact may be discovered by this simple means. If the rod be held perpendicularly, the image will be continued through the fluid without bending, or, in other words, when a ray of light passes perpendicularly through a refracting medium, it is not changed in its direction. As glass spectacles and prisms are much employed, it may be useful to under-

stand the peculiarities of their refracting action. A piece of plane glass merely bends the ray; for instance, if  $r$  (Fig. 9) be a ray of light falling at  $a$  upon a piece of plate glass, instead of proceeding in the straight line to  $b$ , it is drawn out of this course by the refracting power of the body, and takes the new direction  $ac$ , but after emersion, it proceeds onwards in a line parallel with its original route; for the glass or refracting medium only constrains it so long as the ray remains in its limits. If the glass were convex, (a *convex lens*,) the rays would be similarly refracted; but the issuing rays would be brought together after emersion, as represented in Fig. 10. The point of union is remarkably brilliant if the lens be large, and if the eye be placed near it, there will be seen a magnified image of the object from which the rays

Fig. 9.

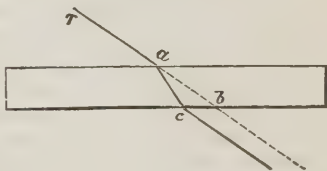
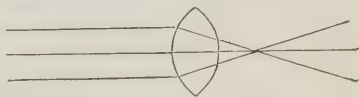


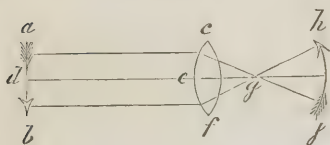
Fig. 10.





have passed. This is a magnifying glass, and has the same optical properties as the crystalline lens of the eye. But in the eye, the retina is not placed at the focus of the lens, but beyond; hence the rays fall upon it after condensation, and depict an inverted

Fig. 11.



image, as will appear from the figure (Fig. 11), in which *ab* is the image, *ac*, *de*, and *b f*, rays proceeding to the convex lens of the eye; here *c* and *f* are refracted, and issue to meet at the focus *g*; subsequently, they diverge again, carrying a picture of

the parts they have passed from to the retina *h j*, which receives the inverted image. For distinct vision, it is necessary that the focal point should bear a certain ratio to the distance between the posterior surface of the lens and the retina, differing with the size of the organ; if this distance be disturbed, vision becomes indistinct; when it approximates to the eye, the individual sees distinctly only when the objects are at a considerable distance. This is the case in the aged, and constitutes the defect called *presbyopia*, or long-sightedness. The remedy consists in the use of spectacles with convex glasses, which aid the crystalline lens in reducing the focal length. The convexity of the lens in such persons, will be found diminished, and sometimes this will amount to flattening. Where the crystalline lens is removed in the operation for cataract, a magnifying glass is set before the cornea to refract the light and answer its purpose.

If the figure of the glass be concave, the reverse effect, or that of minifying, takes place. Such lenses are useful where the defect called *myopia*, or near-sightedness, occurs. The crystalline lens in these cases is too convex, and its focus is in advance of the proper point; but by counteracting this, by means of a glass which causes the rays slightly to diverge before entering the eye, the true point is reached, and vision made clear. Myopia is a defect of youth.

The most valuable instruments of the optician, as the microscope, camera obscura and telescope, are combinations of these two kinds of lenses. The microscope, to which the profession owes so much, is a combination of two or more convex lenses. These are so placed as to observe an object brilliantly illuminated by reflection from a small mirror, or by the condensed rays of a large lens. It is the adjustment which gives to the instrument its apparent complexity, the principle being very simple.

The *optical prism* is a long piece of glass having three equal sides. If a ray of the sun's light be made to pass through it in

certain directions, there is produced an elongated image of great brilliancy, and containing all the colors of the rainbow. This is called the sun's spectrum, or the prismatic spectrum. If the prism  $abc$  be arranged as in the figure, (Fig. 12,) the order of colors will be

Fig. 12.



from above downwards *violet, indigo, blue, green, yellow, orange, red*. In this experiment, it is apparent that the prism refracts the light, but that in consequence of the difference of length through the glass, along which the upper and lower parts of the beam passes, the different rays are separated. The violet, indigo and blue rays being found at the highest parts of the spectrum, are the most refrangible, the red and orange the least so. But the most remarkable result is that the white or yellowish-light of the sun is by no means a simple emanation, but consists of at least seven parts distinguished by color, refrangibility, and in other respects. If we mix colored powders in such proportions as to represent these seven rays, there will be produced a whitish mixture. Moreover, if a colored light be examined, it will be found to contain only a portion of the rays of the spectrum.

The prism is by no means the only contrivance by which we can separate the rays of light. Any reflecting substance which is scratched with minute lines of such a depth that they bear a relation to the breadth of the undulations of light, will exhibit the colors of the spectrum. In these cases, as in the prism, the lengths of the paths of the rays are unequal, and their union, which constitutes white light, is disturbed. If, instead of using scratches or plates of unequal thickness, we interpose in the path of a diverging ray of light, a thin opaque body, as a needle, we find that, at a short distance behind it, the shadow ceases, and lines of colored light, like those of the spectrum, but on a minute scale, are perceived. If the light employed in this experiment be of one color only, instead of the bands of various colors, we discern stripes of black, and of the color employed. This constitutes the famous experiment of *interference*, from the study of which the undulatory theory of light has been proved, and the wave lengths determined. The existence of black bands where there

should be light, arises from the *interference* of the waves, the paths of which are rendered unequal by the obstruction of the opaque body. The effect arises in this case precisely as in the case of sound, where one wave having a length slightly greater than a second, the two interfere, producing intervals of silence. This experiment is readily made, the means necessary being two tuning forks of the same note, and a glass containing water, and vibrating in unison with the instruments. If the forks be sounded, and held over the glass, they produce a loud, clear and uniform note, representing the sum of their vibrations. But if we increase the weight of one slightly by a drop of sealing wax, and vibrate them, the product is not a uniform note, but a sound which swells and subsides, and in which there are intervals of silence and of increase. By altering the weights of the forks, we have made a difference in their tones, not amounting to a whole note, but less; hence the undulations in air produced by them, and which constitute sound, are not uniform. Their paths are unequal, and they operate upon the particles of air with different effects, increasing or neutralizing the vibrations and the sounds resulting therefrom. In the interference of light, the causes and effects are similar, but the phenomenon takes place on a very minute scale. The undulations propagated around the opaque object, have paths of different lengths, hence they come in collision, and the result is darkness in the case of a monochromatic light, whenever the paths differ by less than one undulation, or bear the relations of 1 to  $1\frac{1}{2}$ , to  $2\frac{1}{2}$ , to  $3\frac{1}{2}$ , &c.

By varying this experiment, and using differently colored lights, we find that the stripes vary in width, being widest in the red and orange, and narrowest in the violet and indigo. The study of these and similar phenomena furnished Fresnel with the means of measuring the lengths of the waves of different colors. If we divide an inch into ten millions of parts, the wave lengths will be respectively,

For the red ray,	.	.	256 parts, or	$\frac{256}{10,000,000}$	inch.
For the orange ray,	.	.	240	$\frac{240}{10,000,000}$	"
For the yellow ray,	.	.	227	$\frac{227}{10,000,000}$	"
For the green ray,	.	.	211	$\frac{211}{10,000,000}$	"
For the blue ray,	.	.	196	$\frac{196}{10,000,000}$	"
For the indigo ray,	.	.	185	$\frac{185}{10,000,000}$	"
For the violet ray,	.	.	174	$\frac{174}{10,000,000}$	"

Hence difference of color has a capital and not metaphysical origin, being due to the lengths of the undulations originated by any force. The violet undulations are the most minute, the red the largest. It may be proper to remark, that beyond the least refrangible limit of the spectrum, we find pure heat rays, indicating that the most active undulations of that agent have a greater wave length than red light. The amazing rapidity of the vibrations of the ether in the propagation of light will now appear. This impression is communicated at the rate of 195,000 miles in a second of time, and each wave is but a small fraction of the ten-millionth of an inch. From these numbers, it appears that, if a second of time be divided into a million parts, a wave of violet light vibrates 727 millions of times in this interval. The play of colors seen on iridescent minerals, or the feathers of some birds, and on insects, arises from the interference of rays of light. A perfect spectrum may be obtained from a piece of metal regularly marked with close lines, and when it is produced in this way, it is purer than that of the prism. In the interference spectrum, the bands of colors are of equal widths, the yellow rays occupying the centre, whilst in the prismatic spectrum, the bands are very unequal.

The colors of ordinary objects depend upon the relations of their surfaces to light, some absorbing one ray and reflecting or transmitting others. Black objects absorb all the rays, polished white surfaces none of them. The colors are seldom pure, but are commonly a mixture, which may be made apparent by dispersing a beam passing from them by the prism.

Many minerals and other transparent objects possess a remarkable action on light, when a ray is passed through them in a particular manner; it emerges as two beams, one of which is refracted according to the ordinary power of the body, and the other according to a different force. The first is called the ordinary ray, and the second, the extraordinary ray. Such substances are said to have *double refraction*. Calcareous spar and quartz offer familiar instances of doubly refracting crystals; if either of these be held over a line of writing in a certain manner, we perceive two images.

The two rays are in all cases changed in the direction of their planes. If the two images be examined by a tourmaline, one is found to disappear, as the crystal is turned around.

If a tourmaline be held in a certain direction before a radiant point, light passes through it; but if another tourmaline be now interposed between the eye and emergent beam, and turned about, the light will be found to pass in some directions and be obstructed, and altogether extinguished in others. So, by reflecting light at peculiar angles, (for glass  $56^{\circ} 45'$ , and for water  $53^{\circ} 11'$ .)



it will be found that a portion is transmitted, and another reflected, which latter, if examined by another reflecting surface of glass, is found to disappear, not being reflected as we turn the second glass, called the analyzer, around. The disappearance takes place in two positions, when the plates differ in their angles by  $90^{\circ}$  F. and 180 degrees. In these cases, the rays are said to be polarized, and the process is termed polarization. It may be effected by the action of doubly refracting minerals, by the absorbent action of the tourmaline and other bodies, and by reflection. The effects observed in these cases are attributed to the specific action of the mineral particles on the ether in which light is propagated.

### THE SUN'S LIGHT.

The beams of the sun contain, besides light, other forces, differing in their effects on matter. Heat may be discovered in every part of the spectrum, but the hottest portions are in the orange, red, and beyond the luminous parts. We find, also, that in the blue, indigo and violet portions, there exists a degree of chemical activity much greater than elsewhere. If these rays be made to fall upon the chlorides, bromides, or iodides of silver, gold and other metals, they become decomposed. The same rays effect the union of chlorine and hydrogen, frequently with explosive violence. From these effects, they have been termed the *Chemical rays*, or, more recently, the rays of tithonicity, by Prof. Draper. Indeed, tithonicity has been advanced as a new agent or imponderable; but this view is opposed to the undulatory theory;—the results being produced by the action of vibrations, conveyed through the ether, on the matter of the chlorides and bodies susceptible of change, and not by a new agent; and depending on the state of chemical combination more than on anything else. Chemical changes are produced also by other parts of the spectrum.

The *Daguerreotype*, and other processes of *Photography*, for obtaining pictures by the sun's action on metal and paper, depend upon this chemical power of light. The process of the Daguerreotype consists in acting on a plate of copper covered with silver, by iodine, which yields a rich yellow deposit of iodide of silver. To hasten the sensibility of this covering, the prepared plate is brought in contact for an instant with the vapor of bromine, or the mixed vapors of chlorine and iodine, or otherwise. This is done in a dark place. The plate being ready, is next introduced into a camera obscura, already adjusted to some object, and being inserted in the place of the ground glass of the instrument, it receives the image. The lights of the image impress the sensitive



coat of iodide and bromide of silver producing decomposition, and driving the iodine and bromine deeper into the metal, but those portions which are in the shade are little affected. After a minute or two, depending upon the power of the light and preparation of the plate, it is removed and placed over a mercury bath, to receive the vapor of this metal heated to  $175^{\circ}$  F. The mercurial vapor acts upon those parts of the silver which have been rendered free by the action of light, but cannot reach those still in the state of combination. The plate is next washed with hyposulphite of soda to separate the iodide and bromide, and destroy the sensibility of the surface. After this operation the plate presents a picture in white and black, the former of which indicates the parts where the light has acted, and consists of an amalgam of mercury with silver, whilst the black portions present the polished silver. In the present day, the silver plate is coated with gold, by means of the chloride of gold, dissolved in hyposulphite of soda, to preserve the picture, and is sometimes colored by dusting different powders on the surface.

Other applications of the same principle have been made by Sir John Herschel, Mr. Talbot and Mr. Hunt, for the production of pictures on paper. This department of the art, called *Photography*, originated many years since with Mr. Wedgewood, and Sir Humphrey Davy, who employed a solution of nitrate of silver which turns black on paper in the sun's light.

*Physiological action of Light.*—The study of the above facts is of considerable interest to the physiologist. The structure of the human eye has been for a long time compared to a camera obscura, and agrees in its parts with this instrument. The cornea and iris are intended to limit the field of vision, and cut off those lateral rays which would confuse the picture impressed on the retina; they have the same function as the tube, which is placed before the lens of the camera. The humors and lens constitute a refracting arrangement, answering to the convex lens of the instrument, and the retina occupies the place of the ground glass which receives the image. But the retina cannot be compared to the ground glass of the camera in anything except position; it receives the picture, but not passively. There are changes taking place on this nervous expansion which are precisely in the degree of the light falling, and a communication by undulation is made to the brain of the effects which the rays of light are producing on its sensitive surface. This portion of the eye is closely analogous to the Daguerre plate. It consists of a nervous matter which undergoes chemical change in proportion to the intensity and color of the light, being most impressed by the yellow rays, and least by the violet; and in these particulars differing from the iodized plate, which is most affected by the indigo and violet rays. That

the picture is not passively received, will appear, by considering the action of intense light, which disorganizes the molecules of the retina, and produces inflammation. In this tissue as in every other of the body, there is provision for waste and repair, and the waste takes place, as in them, under the influence of a chemical cause, which in this case resides in the decomposing action of the sun's rays. That a chemical action occurs, may be proved by the fact, that the retina is incapable of receiving images in rapid succession. There must elapse a space of time amounting to about the tenth of a second, between the perfect and consecutive impression of two objects, and if the time be much less, confusion occurs, and the parts of the two become blended.

The luminous appearance of certain insects, as the lampyris, fire fly, and glow worm, has been shown by Matteucci and others to depend upon chemical action, in which oxygen is absorbed, and carbonic acid evolved.

The curious instinct of plants, to incline their leaves and stem towards light, and the movements of sensitive plants are connected with the action of the sun's rays. If plants grow in a room lighted only on one side, they will depart from their accustomed upright figure and bend over to the illuminated side.\* This effect I have discovered to depend on the action of the indigo ray chiefly, and this fact also furnishes us with an explanation of the upright growth of most vegetables, the blue sky being a radiant to which they naturally direct themselves.

But there is no chemical effect of light more important than that taking place in the nutrition of plants. To the leaves of plants there is brought, by the action of the roots and capillary attraction, a store of sap; this consists of water with carbonic acid, saline matters, and a little ammonia. The sun's light acting on the carbonic acid, in the presence of the green matter of the leaf, decomposes it, an effect not otherwise attainable, and by this means brings into existence those compounds of carbon and water which are known as sugar, starch, gum, and which are products destined to sustain the life of man and animals. There is no other means by which these foundation materials of life can be produced, hence it is by no means infrequent in this day, to speak of the sun as the *Fountain of life*. In the paper referred to, I have shown that the green matter of the leaf, called chlorophylle, is brought into existence by the action of the yellow ray of light, which is also operative in decomposing carbonic acid, as Prof. Draper has proved. Being the active agent in the production of

\* This subject with the action of light generally on plants, was made the subject of a memoir by me, and printed in the London and Edinburgh Philosophical Magazine, and Silliman's Journal for 1844, to which the reader is referred for the full particulars.

the organic compounds of plants, it is not surprising that the vigor of development in vegetation should depend chiefly on light.

We have thus pointed out a difference between the chemical and physical effects of the rays of light. It would appear that, whilst the most refrangible rays, the blue, indigo, and violet, and the space beyond them, are influential in producing changes in the mineral compounds of the daguerreotype, and in the inclination of the stem, and movement of the leaves of plants—the yellow, green, and orange rays, occupying the central portions of the spectrum, govern organic combinations; producing by their undulations, the chemical changes in which existence originates, affecting the retina, and governing the capacity of vision—whilst the least refrangible, the orange and red rays, and the space beyond them, take on an action allied to heat, being far more active in the production of chemical and physical effects, and as regards the human body, awakening the sensation of heat. It was formerly the habit of writers, to speak of the solar spectrum as consisting of three or more agents, and to distinguish between the spectrum of heat, of light, of chemical action, or tithonicity, and of phosphorescence; but we incline to the view of Melloni, Becquerel, and others, that these are effects depending on the constitution of the matter, rather than attributable to the independent existence of numerous imponderables. These effects are not confined to the sun's light, but are produced by light, derived from intensely heated sources, or highly phosphorescent substances, as lime, baryta, strontia, or magnesia, heated by the oxy-hydrogen blow-pipe. This, with other facts, point out the nature of the sun, and confirm us in the conclusion that he consists of a mass at an intense temperature.

Light can scarcely be considered a therapeutic agent, but its action on man is not altogether unimportant. Its absence creates a degree of gloominess in the mind, which is remarkably perceptible in the melancholic, whilst its presence excites the senses, and increases the activity of the brain. A cheerful light is of great service to the cachectic, and those suffering from despondency, and insolation has been recommended on physiological grounds to those laboring under scrofula, and anæmia; and is highly conducive, according to Edwards, towards removing rickets in young children. It has been demonstrated that the development of animals, as well as plants, is connected with free exposure to light. On the other hand, absence of light acts as a sedative, conducing to sleep, and, associated with quietude, is very important in the treatment of irritation of the brain or nerves, after parturition, and severe accidents and operations. In most diseases of the eye, darkness is an essential part of the treatment.

The color of the glasses of spectacles, when the eyes are weakly, is also worthy of attention. We find amber, green, and blue glasses used, but these are manifestly different in their effects. The amber-colored and green glasses, allow the active rays of light to pass, and rather exalt the chemical action on the retina; but a light blue, by absorbing the yellow, orange, and green rays, is well calculated to protect the eye. The blue also acts by stopping the passage of a portion of the heat rays, which enter through an amber-colored medium.

In amaurosis, the defect of vision occasionally arises from want of activity in the retina; and the employment of a strong light has been found by Hufeland to effect a cure, when all other means failed; but this agent is to be used only after a thorough diagnosis.

## ELECTRICITY.

THE number of facts in electricity, is extremely numerous but we have, by no means, as good an idea of this agent as of light and heat. There appears to be little doubt, that it is a force propagated by undulations with immense rapidity, and that it produces, like heat and light, both physical and chemical effects, but the difference of its action on matter, makes it more difficult to sustain any theory in electricity. We are also ignorant of radiant electricity, except in the interstitial variety, (*conduction*) and this impedes the application of the undulatory hypothesis: nor do the ideas of Franklin and Dufay, that it is one or two fluids, serve us better. The views of most chemists are, therefore, not matured on this subject, and we believe that Professor Hare\* has been the first, formally to announce his adhesion to the polar or undulatory theory, in some degree sustained by the researches of Faraday.

The subject divides itself naturally into two parts: 1. *Common Electricity*, 2. *Galvanism*.

### § 1. COMMON ELECTRICITY.

The term, common or statical electricity is employed to distinguish the electrical phenomena which result from friction, pressure, or an alteration in the aggregation of the molecules, in non-conducting bodies.

If a cylinder of glass, resin, sulphur or shell-lac be rubbed with a piece of silk, fur, or woollen cloth, both acquire the property of attracting light particles of paper, cork, pith and other substances. This affords an illustration of a capital electrical effect called *attraction*, and is a test of the presence of this agent, every case of molecular attraction being attributable to the action of electricity. But if we suspend a feather, or light pith ball from a stand, and bring any of the above substances *excited by friction* towards it, two actions will ensue, the object will at first move towards the *electric*, and subsequently move away, appear-

\* In his pamphlet, entitled "*Objections to the theories severally, of Franklin, Dufay, and Ampere, with an effort to explain electrical phenomena, by statical, or undulatory polarization,*" Philadelphia, 1848.



ing to be repelled. Hence *repulsion* as well as *attraction* follows as an electrical effect. It is also worthy of observation that those bodies which have come in contact with one of the excited substances repel one another, but those which have been acted on by the dissimilarly electrified substances attract each other, or like electricities repel, and unlike attract. It is not necessary for the production of electrical excitation, that the bodies be different, for one piece of dry silk tissue may be made to excite another, one piece of brown paper another, one glass another. In such cases the two will adhere together. The condition necessary is that the body be not a conductor of electricity, for in this case the agent would pass off by interstitial radiation as fast as it was excited, and produce none of the local disturbances in which the phenomena of attraction and repulsion arise. Matter is therefore divisible into two classes in electricity.—1. *Electrics*.—2. *Conductors*.

*Electrics* are bodies which exhibit excitement by friction, they are also called *insulators*, because the effects of the electricity are retained on them, and do not pass off. It is also practicable to retain the electrical condition on a conductor, by surrounding it with electrics—this is called *insulation*. The brass conductor of an electrical machine is supported by glass and surrounded by air, which are non-conductors. Hence it is like an island (*insula*) cut off from connection with other conductors, and compelled to retain its charge. Excitation takes place in conductors or non-electrics if they be insulated. The chief electrics are glass, resins, sulphur, amber, animal and vegetable matters when perfectly dry, dry air, hair, feathers, furs. These are nearly incapable of conducting any kind of electricity.

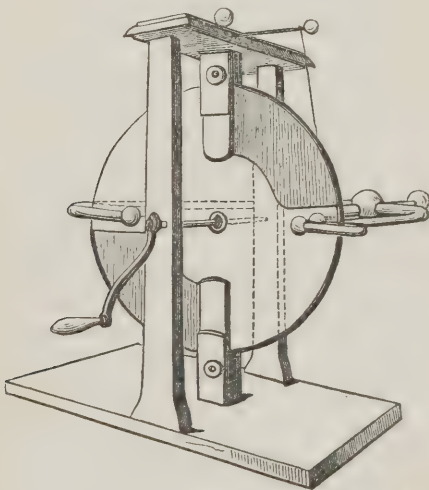
2. *Conductors* or *non-electrics* are those bodies in which the electricity generated by friction or otherwise is radiated or conducted away. These cannot exhibit attraction or repulsion unless insulated. Bodies differ considerably in conducting power, the metals being best; hard charcoal, fused saline bodies, and strong acids are also fair conductors; whilst water and bodies, whether animal, vegetable, or mineral, moistened with it, are the poorest. The human body is a conductor, although not of the best order. Silver, copper, and gold, are the best of all conductors.

The rapidity with which electrical excitement is propagated in a good conductor is equal to the passage of light by radiation, or 195,000 miles in a second; indeed by some the rapidity is thought greater. This rapid passage is demonstrated by the action of the electrical telegraph.

*The Electrical Machine.*—The electrical machine is a contrivance for obtaining a considerable electrical disturbance, and observing the properties of this agent when developed on a large

scale. It consists of a cylinder or circular plate of glass of considerable size, mounted in such a manner as to be capable of rapid rotation. The glass moves with friction between cushions or rubbers of leather, or silk, which are usually anointed with an amalgam of tin, zinc, and mercury, or with mosaic gold (the bisulphuret of tin). These are the parts which generate the electricity, and the machine is set in action, when the plate or cylinder is rapidly rotated. But it is necessary that an insulated conductor should be placed at some part of the glass to receive the electrical disturbance, and serve as a condenser where the excitement may be accumulated. This is usually a cylinder of brass, or of wood covered with tin foil, with rounded ends, and supported on glass legs; it is called the *prime conductor*. Connected with the rubbers is also in many machines a second conductor which may be insulated or not. The figure represents a modern plate machine of good construction.

Fig. 13.



Hence this instrument does not differ in reality from the simple contrivance of rubbing a glass tube with a piece of silk. But when set in action, we perceive several effects which cannot be developed on a smaller scale. Not only are attraction and repulsion made apparent, but sparks are thrown off, and a prickly sensation, sometimes amounting to a sudden spasm, is produced in animals when the excited conductor is touched. Hence the electrical spark,

or where this is not clearly seen, a crackling noise, the phenomena of attraction and repulsion, and the shock are capital tests of electrical disturbance when produced by friction. They are said to be the results of electricity of *tension*, as distinguished from other effects produced by large galvanic batteries, such as the production of heat, which is said to be an effect of electricity of *quantity*; the term tension or intensity being used to distinguish the effects of the machine, and quantity those of certain galvanic batteries. The power of a machine is measured by the length of spark it will give, or the striking distance of the spark.

The study of the electrical machine divides itself into two parts, 1st, the cause of the disturbance on the glass and silk, and 2d, the action of the prime conductor.

The cause of the electrical disturbance is the friction or motion partly, but where the rubber is smeared with amalgam, this acts likewise, being chemically changed. Confining ourselves to the action of friction, all that it is necessary to explain, is that its operation on the surface of the glass or electric is to produce molecular disturbance. Whether we conceive the atoms to be torn off from the surface, or merely pressed, the physical action must produce a result. It is well known that friction on many bodies produces heat; this is especially the case with the metals, which when filled become rapidly warmed. If then heat and electricity are associated in numerous respects, it will scarcely surprise us that an action which will engender heat, may also produce electricity. By friction, then, and indeed by every application of physical force, and in all bodies is electricity disturbed. This disturbance commences in the universal ether, which is in the simplest case thrown into vibrations by the physical force. The vibrations, if there be no interference, will be communicated and create a wave; this is the case in *conductors of electricity*, a result precisely similar to that occurring in the case of heat. And the connection is closer, for the best conductors of heat are likewise the best conductors of electricity. But it has been shown that glass and electrics are non-conductors, hence in such cases the vibrations of the ethereal fluid cannot be propagated, and as in the case of heat, electricity acts upon the molecules of the glass, inducing in them a new state. This new state we term the electrical condition, and it may be said in a few words, that there is every reason to believe that it consists in a movement of the molecules of the matter upon their axes. Conceiving the molecules of matter to be indefinitely small spheres, passive to force, we can understand that whenever union takes place between them to constitute a mass, or when several are combined, there must be some sufficient force to hold them together. This is called *cohesion*, *simple affinity*, or the affinity of *aggregation*. Whatever

be the name, it is a force. It cannot be heat, for this expands matter and dissevers particles; it is not light, for the phenomena of attraction are not exhibited by this agent, hence it is now understood to be *electricity*. The atoms are supposed, under the influence of this force, to arrange themselves in determinate directions, each manifesting at one of its sides an attractive influence, and on the opposite side a repulsive or different action, and, according to the general proposition of electricity, the unlike sides attracting, and the like repelling. Now friction may be supposed to overcome this affinity, and thus set free the electricity which caused it.

*Electrical Polarity and the Magnet.*—As this is a fundamental hypothesis in electricity, it may be useful to support it by a little further consideration. Let the spheres *a b c*, represent atoms of matter. *a* may be taken to represent the abstract atom;

Fig. 14.



in this state it merely occupies space, has impenetrability, definite figure, &c.; but it can exert no influence upon any other atom; it possesses *inertia*. In nature there exists no such abstract atom. On the contrary, all atoms exhibit attraction or repulsion to other atoms; this satisfies us that there is something operating on every molecule, and that it is a force. Hence the atom, practically, is always associated with force, and this may be represented in figure *b*, by dividing it by a line, and conceiving that the force operates differently on either side. That on the one side, it renders it attractive to those molecules which are repelled by the opposite side. The force will be dispersed over the surface of the sphere, but more concentrated at two opposite points, (Fig. *c*.) *p p'*, which are called its poles, and the line between these is termed the axis of the molecule. Such a molecule may be likened to a geometrical globe; the line representing the division between the two parts is the equator, the points of greatest activity are the poles, and the line between them the axis of the globe: to continue the simile, the molecule may be changed in direction by the application of force, and it may revolve around its axis without disturbance of position, as respects the poles; or the axis itself may be made to revolve, causing the poles to change their places with respect to surrounding atoms, or both motions may occur at the same time, under the influence of two forces. The student will now understand what is meant by the *polarity of atoms*, and by *electrical polarization*.



A familiar instance of the polarity of particles is offered in the magnet. There is a natural magnet, which is an ore of iron; the artificial magnet, made by rubbing a piece of steel in certain directions with the ore, and also by other processes; and thirdly the magnet formed by the action of electrical induction or the electro-magnet. In each of these we find that one end of the magnet possesses different properties from the other, and if we bring first one end and then the other, to a magnetic needle, it will be attracted by one and repelled by the other. The ends of the magnet are therefore called by different names, one being the marked end, *North, or boreal pole*, and the other the south, or *austral pole*. When like poles are brought together, repulsion occurs; when unlike, attraction, which is the fact in every case of electrical disturbance. That this is an instance of electrical action, can be shown by the instantaneous production of a magnet, by the action of electricity. Nor is this diversity, or polar action peculiar to masses, for, if we reduce the magnet to the size of a fine needle, it will be apparent, and if this be broken in a number of pieces, each part exhibits a *positive* and a *negative pole*. Hence, a magnet is made up of one or more rows

Fig. 15.



of atoms, every one of which atoms has polarity. The figure (15) represents the theoretical structure of the magnet; it consists of atoms, each of which has a positive and negative side and poles, represented by the white and black parts; the atoms in the same line or axis, are united by their dissimilar poles, so that the ends of the magnet consist of negative or positive sides only. The power of the N and S poles, depends upon the free ends of the atoms which are not in union, and which exercise at all times attractive or repulsive powers towards certain bodies.

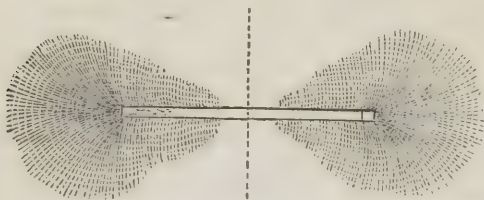
The dependence of the polar state upon the action of a force, is made apparent by the fact, that the magnetism of a bar of steel may be destroyed by striking it, applying heat, or passing a strong current of electricity through it, in a direction opposed to the arrangement of the atoms. Indeed one magnet will neutralize another, if they be placed above each other, and in opposite directions.

The polarities of the magnet affect circumambient matter, as may be seen by dipping either end into fine iron dust, when particles of the iron will adhere. If we place a sheet of paper, or a pane of glass, over a bar-magnet, and sprinkle it with fine iron filings, they arrange themselves in regular lines, (Fig. 16,) each atom of iron acquiring regular polarity. Hence the electrical force of the



magnet is capable of producing effects beyond the steel, and if we measure them, we find that they diminish, as in the case of

Fig. 16.



heat and light, inversely as the squares of the distance. The connection between these forces is further increased by the fact that some bodies allow the passage of the magnetic influence, as paper and glass; whilst others, as iron, and probably cobalt and nickel, will not let it pass, but retain or absorb it, giving out electrical effects. In the same way, then, that blue glass absorbs some rays of light, and becomes colored thereby, iron and steel absorb electricity and become magnetic. The space immediately around a magnet, is called the *magnetic atmosphere*; and objects in this space are subjected to a radiant influence, which is of an electrical kind.

From the study of the magnet, we therefore arrive at three conclusions:

1st. That atoms under the influence of the electrical force exhibit polarity.

2d. That when the force is considerable, the polar influence may reach distant objects, and affect them, producing electrical excitement by induction.

3d. That this radiant influence may be transmitted, or otherwise, according to the nature of the matter; glass allowing it to pass, whereas iron does not.

These facts are important in every portion of electrical or chemical science, for the latter is but a part of electricity. It has been pointed out, that *cohesion*, or the simple aggregation of matter, is the effect of a force which we infer to be the electrical force; it will be shown in the sections on *chemical action* and *capillary attraction*, that these are likewise cases of electrical action. Or, in other words, that simple *cohesion*, *complex cohesion*, or *capillary attraction*, and *chemical affinity*, are cases of electrical action, differing principally in degree.

To return to the electrical machine. The glass, by friction, has its ether thrown into motion; this motion not being propagated, because glass is a non-conductor, affects the molecules of the plate. It is analogous to the action of heat on a non-conductor,

the vibrations not being propagated, the body expands, or even burns, because of the force operating on the matter. Hence, in the machine, the atoms of the glass are put into a new state, by an increase of force; they may be supposed to be thrown into revolution, or to have their polar axes disarranged. The same occurs in the rubbers.

*The Prime Conductor.*—We are now prepared to understand the office of this part of the machine. The forced atomic state of the glass, cannot be equalized, except after some time, in the air; because air and the glass are non-conductors. But, by placing near to the surface of the plate, the branches of the prime conductor, which are usually furnished with numerous metallic spikes, the glass, as each portion passes near the spikes, propagates some of the electrical influence with which it is charged. The atoms of the glass may be supposed to fall back, more or less completely, into their unexcited state. This depends upon the rubber and conductor; or, if both are insulated, electrical phenomena are little developed, and polar effects in each part of the machine arise; but when the rubbers are put in connection with conductors, so that every disturbance on that side is neutralized by its rapid propagation, the molecules of the glass are nearly relieved in the first turns of the instrument. When both the rubber and prime conductor are insulated, one is found to exhibit positive, and the other negative electricity, and the machine may be likened to a magnet, of which these parts are the poles. We find them, like the poles of the magnet, exhibiting attraction and repulsion dissimilarly, and exerting polar effects.

To obtain an active electrical state, the rubber must be connected by a conductor to some mass, as the earth, which will be scarcely affected by its disturbance, so that its polarity may be neutralized at every turn. The excited glass discharges a portion of its force on the spikes of the conductor; this is propagated to all parts, and polar disturbance soon arises, because the metal is insulated. With each turn, this polar disturbance increases; it is rapidly communicated to the air, and finally it becomes so intense, that molecular action occurs in the air; a brush of light darts off the conductor at any projecting part, or a flash of electricity takes place to any conductor within a few inches. This is the discharge of the prime conductor. The flash, or spark, is an effect of the molecular disturbance; it is not the electricity, but is a result of compression and chemical action on the air, arising from electrical force, and attended by the production of light, heat, and chemical effects. The sound accompanying the spark, is due to the concussion of the air, and is produced in the same way as the thunder which accompanies the flash of lightning. That physical effects are produced by the excited conductor, may be readily shown: for, if we adapt to it a rod

terminating in a point, a current of air will issue from the point, when the instrument is in action, which may even blow out a candle. Again, if melted sealing-wax be placed on the prime conductor, and the machine set in action, the wax will be spun out in fine threads, being projected to the nearest conductors. Many pretty electrical toys are made to illustrate this fact; such as the electrical tree; the electrical orrery.

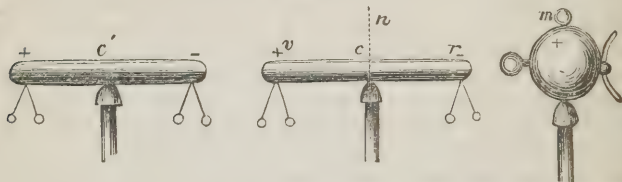
The air around every excited body is disturbed, the molecules being polarized in a direction opposite to the insulated conductor, and serving by pressure to retain the charge on the prime conductor. As the excitation increases, the pressure of the air increases. This phenomenon is also perceptible in other, if not in all electrics; it takes place in glass, paper, and resins. But as we have seen, in the discharge of the prime conductor; there is a point where a limited stratum of an electric cannot retain a charge. The spark or discharge occurs through air, tearing it asunder; it also takes place through glass, breaking it in pieces, and will perforate a piece of card board with great facility. And if we use a card glazed with carbonate of lead, we find that the electrical discharge not only produces the mechanical effect of tearing a hole through it, but the chemical action of decomposing the carbonate of lead, and producing a black stain. Numerous instances of chemical change may be given, as the combination of oxygen with hydrogen to form water, oxygen with nitrogen to form nitric acid, the burning of cotton, ether, and other bodies.

**ELECTRICAL INDUCTION.**—The molecular disturbance giving rise to the phenomena of electricity is propagated in every direction, and induces similar changes in surrounding matter. If the excited parts are in contact with conductors, there is an electrical wave propagated, whatever be their length, and we are not cognizant of any action unless the continuity be interrupted, then it will be found that the dissevered ends exhibit polarity. If the conductor be poor, as water, or moist animal substances, the propagation becomes impeded, and chemical decomposition, disturbance of aggregation, or other effects arise. The spasmodic action denominated a shock, takes place if the human body be the conductor. On the other hand, if the excited substance, for instance, the prime conductor of the machine, be surrounded with non-conductors, or di-electrics, a wave cannot be propagated, but the molecules of the body are each affected, and arrange themselves in a manner similar to the particles of iron acted on by a magnet. Professor Hare, in the memoir before cited, adopts the idea that this difference of conduction, or molecular arrangement, may arise from the state of the universal ether in the two classes of bodies, in conductors it being condensed, and in dielectrics rare. It would appear, however, to be also connected with the facility with which

the polar state is assumed, conductors taking it on readily, whilst non-conductors are more slowly but permanently affected.

The propagation of the electric influence through air, glass, resins, sulphur, and dielectrics, affects conductors placed at a distance from the excited body, inducing in them electrical disturbance. Hence induction is one of the chief means of producing

Fig. 17.



free electricity. In the figure (17), *m* represents the prime conductor of an electrical machine; it is powerfully excited, and has the +, plus, positive or vitreous electrical polarity; it is insulated below by a glass stem, and around by air, which is one of the best dielectrics when dry. The atoms of the surrounding air have their polarity so affected, that on the sides towards the conductor they are negative or resinous, and on the remote sides positive. The row of atoms lying between *m* and *c*, which is an insulated metallic conductor, are affected in this way, all the sides towards *m* being resinous (*r*) or positive: *c* is, therefore, rendered, —, negative on the side nearest these aerial atoms, and its molecules propagating the electrical influence, exhibit polarities in such a direction that all the — sides are towards the end nearest the prime conductor, and all the + sides (*v*) in the opposite end. The ends *r*, *v*, not being neutralized by combination, exhibit, like the poles of the magnet, free electricity and the phenomena of attraction and repulsion, as may be seen by suspending light pith balls at these ends, when they will diverge and thereby indicate free electricity. The influence propagated through the air by the prime conductor *m*, is now propagated by *c*, and reaches *c'*, where similar effects arise; thence it may pass to others, through a series depending upon the power of the machine, the interval of dielectric or air, the conducting quality of the insulated conductors, &c., but in every case diminishing from *m* as the squares of the distances when the same conductors and dielectrics are employed.

The molecular arrangement of the dielectric may be rendered evident to the eye by a simple experiment. Take a glass tube furnished at both ends with a brass ball so as to close it, and containing oil of turpentine which is a good dielectric, in which a number of short threads of sewing silk, also a dielectric, float; apply one ball near the prime conductor, and let the other touch



the table. When the machine is set in action, an influence will be seen to act on the floating filaments of silk; they soon arrange themselves end to end, and become a medium of electrical propagation, lying like threads between the two balls. If the excitement be very strong, the molecules of the oil will exhibit rapid currents from one electrified conductor to the other. In this experiment, the filaments of silk represent the molecules of air lying between two conductors. The production of currents in the oil is analogous to the production of the *electrical brush*, and *electrical aura* or wind from points, which is a physical effect of electricity of high tension, and of the same character as the action on air which produces the snapping report, and flash of the electrical discharge.

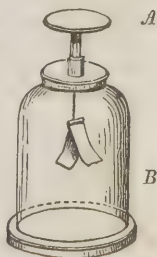
Induction does not take place through all dielectrics in the same degree. Professor Faraday has measured the inductive power "or *specific inductive capacity*" of the principal dielectrics, by means of an instrument called the *Inductometer*. This consists of a contrivance by which sulphur, resins, glass, air, &c., can be placed between two conductors. With the same charge of the prime conductor, the second conductor placed at the same distance in all cases was charged through air 100; through shell-lac 200; through flint glass 176; and through sulphur 224. Hence shell-lac and sulphur have the best inductive capacity. All gases, whether of different density or temperature, appear to have the same inductive capacity.

Induction is one of the most common and important of all electrical phenomena. If any substance be approached to an excited substance, it is thrown into the electrical state. On this principle are constructed a number of useful and important instruments for testing the presence of electricity called *electroscopes*, *electrometers*, and also the electrophorus and Leyden jar. Many of the supposed cases of electricity by contact, may also arise from inductive action.

*Electroscopes*. An electroscope is a contrivance for the detection of electrical disturbance. Two are commonly employed: the pith ball electroscope, and the gold leaf or Bennet's electroscope. The first consists of two pith balls, connected by a linen thread, and suspended on a metallic rod. If it be brought near an excited substance, the balls diverge, and the degree of their divergence is a coarse measure of the amount of excitation. The gold leaf electroscope is depicted in figure 18.

The cap *A* is of brass and connected by a metallic rod with the gold leaves. The body *B* is an open glass vessel, on the inside and lower

Fig. 18.





parts of which are pasted strips of tin foil, reaching to the stand and not insulated. When there is no electrical excitement, the gold leaves hang down, side by side, but if an electrified body be brought over the cap *A*, the leaves immediately diverge, flying apart to the pieces of tin foil. This occurs whether the body exhibit positive or negative polarity. But if the gold leaves are in the act of divergence under the influence of a positive surface, and one that is negative be now brought, they immediately collapse. This instrument may be employed to determine the state of the electricity, whether it be positive or negative. For this purpose an excited piece of glass or resin is employed, the former imparting the negative (—) and the latter the + condition to the gold leaves. This is accomplished by first bringing the electrified substance to the cap, divergence is produced, then touching the cap with the finger and removing together both the electrified body and finger. The leaves, instead of falling back, as is usually the case, remain apart and changed with the positive or negative influence. If now a body with like excitation be brought, the leaves diverge farther; if with the opposite electricity, they collapse. If the leaves be positive, a negatively electrified substance can be recognized by its power of causing the leaves to come together, and the reverse. Besides these instruments, there are two designed to measure quantities of electricity, Coulomb's torsion electrometer, and Harris's balance electrometer. The former is a beautiful instrument, and measures the amount of electrical force in the repulsion of a gilt pith ball, by the torsion or twisting of a fibre of silk, or thread of glass. It is employed only in delicate researches, and has been used in the development of the principal facts in the distribution of electricity.

The *electrophorus of Volta* is a cake of resin, on the upper side of which, is placed a disk of metal, furnished with a glass handle. When used, the resin is excited by a piece of flannel, and exhibits resinous or negative polarity; it therefore induces a change in any neighboring conductor. If the plate be now placed on it, the lower side becomes positive, +, and the upper —, negative, by induction, and if now we touch the upper side by a conductor, connected with the earth, its negative polarity is destroyed, and the entire surface becomes positive. Upon separating the plate from the resin, a spark may be obtained by touching it. The electrophorus will retain its excitement under some circumstances for weeks or even months.

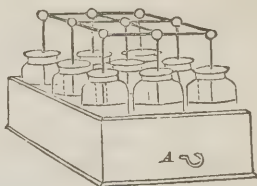
The *Leyden Jar*.—This is a wide mouthed jar of glass, stopped with a piece of baked wood, through which runs a brass rod, having above a knob, and terminating below in a chain. The

sides and bottom of the jar are coated, both inside and outside, to within a quarter of the height, with tin foil, as in fig. 19.

Fig. 19.



Fig. 20.



This is one of the most important electrical instruments, for by its means, we are enabled to obtain charges of great power, and by placing twelve or more in a frame in such a manner that all the brass knobs communicate, and all the exterior tin foil is in contact, the most powerful effects of artificial electricity have been procured. Such a contrivance is termed the electrical battery, and is depicted in fig. 20.

The jar is charged by placing the knob near the prime conductor of the excited machine; spark after spark passes, and is conveyed to the interior tin coating, by which it is distributed to the glass, there producing the molecular effects observable on dielectrics. That this occurs in the Leyden jar may be readily proved, for if we insulate it, and hold to the exterior coat a conductor in contact with the earth, there will pass a spark from this, every time one reaches the inner tin foil. In this case, the disturbance of the interior surface of the glass, is communicated to the exterior by polar arrangement; and the jar cannot be charged to any extent, unless the exterior conducting coat of tin foil will adjust its degree of excitement to that of the glass, which can only be done by placing it in contact with a large mass, as the earth. As the action increases, we discover a peculiar crackling or fizzing sound, which warns the operator that the jar is fully charged; beyond this the glass may be broken by the depth to which the molecular change is propagated, or a spontaneous discharge will take place. This instrument evidently affords us an illustration of inductive action: for the exterior conductor is as actively polarized as the interior, and their condition is the reverse, the exterior being —, negative, when the interior is +, positive. The electric condition of the glass is also certain; for if instead of the jar, we take a large tumbler of glass, and place inside

and outside a cylinder of tin-ware to represent the coatings, we can remove these parts, allow the two tin cylinders to touch, and, on placing them together again, it will be found that the vessel is still charged. The glass being a non-conductor, has retained its excited state, and it is upon this that the action on the foil depends, the metallic portion serving to equalize the distribution of the force only. Such a contrivance is called the *dissected Leyden jar*.

To discharge the jar, we place a conductor, or a metallic rod between the exterior coat and the brass knob, which forms a part of the interior conducting surface. If this could be effected with so much suddenness that no interval of time existed between the application of the discharging rod to the two parts, simple conduction would occur along the metal, and a molecular equilibrium be attained, more or less completely, in every part of the jar. But such an application is impossible, for as the metal of the discharger, especially if it have a knob, is about to effect the communication, a loud snap with the evolution of a bright light and heat is observed. This is no more than an intense spark, which, as from the prime conductor, is more brilliant and has a greater striking distance as the excitement increases. In the case of lightning, it is the discharge of thousands of acres of surface, and has a striking distance of miles, a brilliancy equal to the sun's light, and an intense temperature. The heat, light, and sound, are effects produced on matter, and not the electricity.

The jar is not completely deprived of excitement by the first discharge, there is usually enough to produce a *secondary* discharge. When the dielectric is of shell-lac, sulphur, &c., the number of discharges, after one application to the prime conductor, may be as great as five or six. These subsidiary discharges arise from the presence of a little remaining excitement; this seems to depend upon the degree to which molecular disturbance had been effected; when it is intense, a portion continues, and still acts, inducing the polar state in the conductors, and this leads to the production of another spark, when connection is again made by a metallic rod. The common discharger in electrical experiments is depicted in figure 21; the branches are united by a hinge joint, which enables the experimenter to adapt the distance of the brass knobs to the jar employed. The handle is of solid glass.

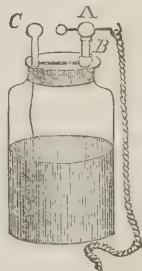
Fig. 21.



If we discharge the Leyden jar by means of imperfect conductors, a variety of actions are produced. On placing cotton, dusted with powdered rosin, over one of the knobs, it will be inflamed. If we discharge it by a wet string, in the course of which there is a break containing

gun-powder or ether, they will take fire. If the right hand of a man be applied to the exterior tin foil, and the left to the brass knob, a startling shock takes place, increasing in severity with the size of the jar, and degree of the charge. As this shock is sometimes employed in chorea, and other nervous disorders, and the shock to be employed may not be the same in all cases, Mr. Lane has invented a machine for regulating its violence. It is called Lane's graduated discharger. The figure (22) exhibits one of these attached to a Leyden jar. It consists of a metallic rod *A*, furnished with a knob at either end, or a chain at one end; and supported by a glass upright *B*. It is capable of motion, and may be brought near to the knob *C* of the jar, or withdrawn. The violence of the shock depends upon the distance at which it is set from the knob of the jar, for a discharge will take place as soon as the striking distance is equal to the interval. By means of this simple instrument, the physician who desires to increase the activity of the shocks, can do so by regulating the striking distance, his patient touches the exterior with one hand, and holds the chain with the other.

Fig. 22.



The discharge along the conductor takes place through an interval of any length, whether it be feet or miles, and with amazing rapidity. A number of persons, holding each other by the hands, will be simultaneously affected.

If there be a choice of objects, the discharge will always take place through the best conductor. It is in consequence of this fact that the passage of electricity appears to be so capricious. Lightning will always strike the best conductors; hence, if we erect metallic rods, of copper or iron, against the side of the house, it will pass along them, if they be well connected with the earth, rather than through the bricks. Trees are very liable to be struck, because they are good conductors. What is called the capricious course of the electrical discharge depends, however, upon another fact, namely, that electrical currents produce induction, or induced currents in an opposite direction. Of this we shall treat under the head of galvanism.

*The Distribution of Electricity.*—The excited or polar state, constituting common electricity, is only to be detected on the surfaces of bodies. The distribution is also dependent on their figure. On a perfect sphere, every portion is equally excited, but on an ellipsoid, the ends evince a greater activity than the central parts. As the conductor becomes elongated, the electrical excitement accumulates more and more towards the ends, pro-



ducing a state similar to that of the magnet. If the prime conductor be a wire, the length of which is very considerable, in comparison with the breadth, the ends will become active poles, whilst the central parts exhibit little electricity. In such a case, if the ends be pointed, the electric pressure of the air or other dielectric will be so little, that a powerful charge cannot be retained, but exerts itself in creating currents in the air, which reduce the electric excitement of the conductor. By means of a pointed metallic rod, the most powerful charge of a jar may be removed, the electricity producing a stream of air or aura, which destroys the excitement. Hence, the prime conductor of a machine should have no points, except towards the glass plate. And, for this reason, it is preferred to terminate lightning rods with a number of points instead of a sphere. The points in this case should be of platinum, a substance that does not rust in the air, and is not fused so readily as iron and most metals. Pieces of thread, hairs, and particles of silk, will also discharge an excited conductor.

**MEANS OF ELECTRICAL EXCITEMENT.**—Two capital means of exciting electricity, have been considered, *friction* and *induction*, but there are others, as *change of aggregation*, *chemical action*, *contact*, and *heat*.

*Contact* is placed amongst the means, but it only disturbs the electrical state in some cases. If we place a dry piece of plate glass on the surface of pure mercury, the two substances adhere, and with considerable force, constituting a case of heterogeneous affinity or capillary attraction; on separating them, there will be found considerable electrical excitement, as may be seen by the use of Bennet's electroscope. But a wet glass placed in contact with mercury exhibits no electricity. To develop electricity in such cases, the bodies must have an attraction for one another, the result of which is a polar adjustment of the surfaces coming together, such that electrical polarity ensues. Some authors doubt whether this occurs without the previous preparation of one of the bodies by heat, friction, or other means, but in the case quoted, such adventitious assistance does not seem necessary. The plate must be merely dry. The numerous instances of capillary attraction, as in all cases where fluids wet a surface, or wet one another, seem to depend upon the production of the polar state by contact. It is not necessary that the bodies be dissimilar, for two pieces of plate glass, two masses of metal will adhere, if brought sufficiently close, and upon separating them, and testing the state of the two surfaces, by proper means, one will be found positive, +, and the other negative. This is the principle of *cohesion*. In such cases the action of the force is very feeble, and Sir I. Newton has determined, that for its deve-



lopment, the surfaces must be brought within at least a millionth part of an inch of each other.

*Heat* produces the electrical state in many minerals, as the tourmaline, boracite, &c., and it indirectly brings it about by destroying the aggregation of matter; as in evaporation. If two wires, metals or conductors, having different conducting powers for heat, be brought together at a small surface, and made fast by twisting, soldering or otherwise, and the junction heated, an electric disturbance occurs. Such an instrument is called a *Thermo-electric* pair, and this kind of electricity, which is not, however, peculiar, *thermo-electricity*. The best metals for this purpose are bismuth and antimony, or platinum and copper. The degree of disturbance varies with the metals, and does not appear to be proportionate to the heat employed. If a number of small square bars, of one-sixth inch width, and about one and a half to two inches long, of bismuth and antimony, be taken and soldered together in pairs at both ends, so as to establish a communication between the whole number, we have one form of the thermo-electric battery employed by Melloni and Forbes in their researches on heat. The metals may be insulated by a film of paper or silk, and bound up in a wooden case. From the terminal bismuth and antimony, proceed copper wires to conduct the polar state of the battery to any desired point. Heat acting on one of its surfaces, so disarranges the molecules of the bars, that they become polarized, and this action being increased by the number of the pairs, a considerable influence is propagated to either terminal wire, one of which forms the positive or +, and the other the —, or negative end of the arrangement.

*Change of Aggregation.*—Electricity is evolved when a fluid passes into the state of a vapor, or a solid into a fluid. Common evaporation and the production of steam are, therefore, sources of electrical disturbance. Simple expansion, in some instances, disturbs the electricity, and rupture does so in others. If a piece of mica be torn in two, the broken ends exhibit different polarities.

The electric state of clouds is supposed to depend upon this action, the vapor rising from the earth, being surrounded by the non-conducting air, retains its excitation until it becomes aggregated again into a cloud; here the molecules combine, and their free electricity is destroyed, but the surface of the cloud exhibits powerful polarity. That vapor rising from the earth is in an electric state, may be shown by placing a little metallic vessel containing water, on the cap of Bennet's electroscope, and dropping into it a piece of red-hot metal or a live coal; steam is immediately formed and the gold leaves diverge. The remaining water

will, in this case, be found —, negative, and the vapor +, positive. A cloud positively charged is like the prime conductor of the machine, producing induction in all matter near at hand, and throwing off a spark or flash, whenever it is sufficiently near, or within striking distance of a tree, mountain, or other conducting body.

It appears, from the experiments of Pouillet, that electricity is also produced in ordinary combustion. For, if carbon or hydrogen be burnt in contact with the cap of the electroscope, the rising vapors are positive, and the residual bodies negative.

The production of electricity by *chemical* action, constitutes the department of the science termed *galvanism*.

#### MACHINE ELECTRICITY IN MEDICINE.

The electrifying machine has been long in use for medical purposes. Its action on the body, in the production of shocks, the prickly sensation of the sparks, and the effects of lightning, induced the profession to expect great results from its employment. These expectations have been, for the most part, disappointed, but there often occurs cases when the use of the machine may be necessary. Patients sometimes exhibit great faith in its effects, and there is a large number of cases in which it has been supposed to be useful.

The agent is applied in a variety of ways,—by shocks from the Leyden jar; by directing currents through certain parts; by placing the patient on an insulated stool and in connection with the prime conductor of the machine; or by directing a brush of electricity from a pointed conductor on some portion of the body. These various ways have received different names, and are employed in diverse affections.

*Shocks* are employed in chorea, and diseases in which a want of nervous activity exists, as nervous deafness, amenorrhœa and partial paralysis. The violence of the shock is to be regulated by Lane's medical electrometer already described. As a general rule, it is best to begin with slight shocks from a pint jar, and increase them as indicated, for there is considerable difference in people as regards the action, some being much affected and pained by shocks which scarcely affect others. The common method of administering the shock is, for the patient to hold in one hand the chain connected with the electrometer, and touch the exterior coating of the jar with the other; in this way the effect is felt in the elbows and across the chest, and may be useful in pleurodynias, or slight muscular or nervous affections of the chest, but can be of no service in diseases of the spine or pelvic viscera. The shock must be directed along or through the parts affected; thus in cases

of partial paralysis of the legs, it must be passed from the lumbar region over the spine to the foot, and be taken at different points along this course. For this purpose, dischargers of a particular make are used, they consist of a glass handle, supporting a curved brass rod with one brass knob, which may be placed in contact with the Leyden jar by a chain. In using them, the knob of one is placed over the spine or other part, and a connection established by a brass chain with the exterior coating of the jar; the other, which is attached in the same way with the knob of the jar or with Lane's electrometer, is then brought over the other part of the body. The shock is thus driven through any part of the system between the two places of application. In amenorrhœa, one of the dischargers is moved over the lumbar vertebræ and sacrum, and the other placed over the pubis. In this complaint, where it arises from an enfeebled state of the body, the agent seems to be very useful, and is recommended by the highest authorities. In the early stages of the paralytic state, arising from nervous debility, some have found shocks driven through the parts from different points of the spine useful. It is necessary to use electricity steadily and for weeks before we abandon it. Whether, in such protracted cases, it be the beneficial agent in the event of cure, cannot be readily determined, but if it does no harm, and the patient desires its use, the physician is not warranted in refusing the application.

*The Electric Bath.*—When the patient is placed on an insulator, as a stool sustained on glass legs, and put in connection with the prime conductor by a chain or otherwise, he is said to be in the electric bath. By this arrangement he becomes a part of the prime conductor, and the same electric excitement is communicated to the surface of his body as exists on that part of the machine. In a dark room, the prominent points of the body, especially the hair of the head, will be found to emit a pale electrical light. In this situation, some persons experience considerable warmth, occasionally copious perspiration occurs, the pulse is quickened, and a sense of formication on the skin is experienced; but, in others, there is little or no effect. The imagination is, probably, more active in all cases than the electricity.

If we apply a conductor, as the knuckle to the skin of a person in this bath, a spark is seen, and the patient experiences a prickly sensation. It is for the purpose of obtaining such sparks that the insulator is generally employed, and the knuckle, or a brass rod terminating in a knob, held in the hand of the operator, is usually employed. It is found, that if a piece of flannel be placed on the skin, and sparks taken rapidly through it by the conductor, in the direction of the nerves, the effect is more permanent than if taken simply from the skin. This method is

called *electric friction*, and was much recommended by Cavallo, Woodward, and others. Electric sparks are supposed to be beneficial in resolving slight tumors, the stiffness of joints, in exciting the organ of hearing in nervous deafness; it has also been employed in atonic amaurosis, numbness, rheumatism, and to excite the biliary function in jaundice. In all these cases, the striking distance of the spark is to be varied, and electric friction employed so as to derive whatever advantage may flow from the use of the agent. Slight shocks may also be used in the above cases, before the electrical treatment is abandoned.

*The Electric Aura.*—The brush, or aura produced on a pointed conductor, has been used in amaurosis, and applied over ulcers. It may be taken from the insulated patient by a pointed conductor, or administered from the prime conductor by a pointed discharger.

The *current of electricity* is also spoken of; in this case the patient merely holds the prime conductor, but no effect is discernible, and it is not worth while to allude to it further as a remedial means.

In reviewing the subject, it appears that some advantage does undoubtedly flow from the employment of frictional electricity, and that it is most indicated in diseases connected with a want of nervous power. In such cases, it may excite the secretions, especially those of the liver and uterus. It is also to be considered favorably in those cases where a loss of function arises from nervous prostration, general or partial. Whether it promotes absorption, as was formerly supposed, is doubtful. In chorea, partial paralysis and chronic rheumatism, there is a host of evidence in its favor.

What the method of cure is, cannot be readily determined, but from its superior efficacy in nervous complaints, it appears to act upon the nerves or their centres. The subject will be resumed under Galvanism.

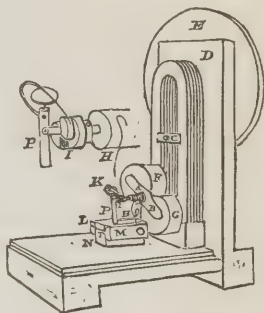
*The Magnet as a Remedial Agent.*—The native loadstone, a magnetic ore of iron, has been long used for remedial purposes, and is, to this day, employed in some countries. It was formerly supposed to be a specific in gout and rheumatism, and to have great powers. Neither this body nor the artificial magnet are employed by the profession in the United States or in Great Britain, but the Germans are zealous in their use. They speak of it as of value in neuralgia, toothache, rheumatic pains, and nearly all nervous ailments, as spasmodic asthma, palpitations, angina pectoris, gastrodynia. Laennec recommended the use of oval magnetized plates over the chest in angina pectoris. One of the plates was situated over the precordial region, and the other on the back immediately opposite, and the dissimilar poles were placed next



the skin. The magnet, simple or compound, straight or curved, or broad plates magnetized, are employed according to the nature of the part. The south and north poles are to be alternately tried, for it is said that one may produce an anodyne effect where the other increases the pain.

We know nothing of these effects, but it is very certain that a powerful common magnet produces no impression on the body in health. There is a machine (Fig. 23), invented by Clarke, and another by Saxton, for generating an electrical current by the rotation of an armature of iron, *F G*, covered with fine wire, near a permanent magnet *D*, or the reverse, which has been extensively employed. In this case a feeble current, similar to that of a galvanic battery, is generated, and called the *magneto-electrical current*. This machine was used in the same cases as the galvanic battery which it has nearly superseded, but has in its turn given place to the *galvano-magnetic machine*, or *electrotome*, to be described in the next article. It is expensive, loses its power, and produces no peculiar effects.

Fig. 23.



*Other Effects of Electricity.*—Frictional electricity can be obtained only during dry cold weather; if the air be damp, the power of insulation is destroyed, and the effects of the machine become very feeble. It is not, therefore, to be depended on as a force for the production of chemical or other results, and is replaced by the galvanic battery in most cases. It has been remarked that electricity produces chemical union and other effects, and in a few cases, the spark is employed to this day, as in the detonation of oxygen and hydrogen, in the analysis of gases.

Atmospheric electricity has been supposed to be peculiarly favorable to the development of plants, but of this we have no evidence, all attempts made to employ the agent in the cultivation of gardens having failed. In the state of lightning, atmospheric electricity is a powerful and destructive agent, destroying life instantly when the stroke is direct, and frequently doing so even at the distance of several feet from the stricken object, by induction. Where life is not extinct, rest, and the removal of all disturbing agents, appear to be necessary. Warmth to the skin, counter-irritation, and sometimes artificial respiration, are indicated; but the physician relies on the recuperative powers of the body chiefly, being prepared to meet any secondary effects of inflam-



mation or debility which may arise. It may be proper to state, that in a thunder storm the safest places are those removed from the neighborhood of elevated or conducting objects, and it is better to be in the lowest parts of a house than upstairs, and to lay down on the ground than to stand erect. There is no fear to be apprehended in a storm unless the flash and thunder occur simultaneously, for as the distance becomes greater, the interval between them increases.

## GALVANISM.

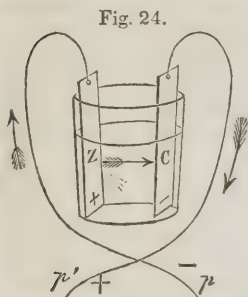
GALVANISM owes its name to Galvani, an Italian, but if the true investigator of this form of electricity is to be honored, it should be called Voltaism, from Volta. The distinction between galvanism and electricity is usually said to arise from the imponderable being in motion in the former case, and stationary in the latter. Hence, frictional electricity is often called statical electricity, and galvanism, with thermo- and magneto-electricity, are said to furnish instances of dynamical electricity. This means, that the phenomena depend upon the conducting powers of the matter affected, and that electricity arises in non-conductors and insulated bodies, but that whenever the force is propagated, it is called galvanism, &c. The distinction not being in the agent, it will scarcely surprise us that galvanism should produce molecular effects in the same way as statical electricity. Indeed, we know little of galvanism, except when the course of the agent is impeded by non-conductors, or inferior conductors, or, in other words, when it produces electrical or molecular effects. The galvanic current must be interrupted to allow us to see its effects of heat, chemical action, or on the animal.

Galvanism appears to differ in another respect. In common electricity, the action is confined to the surfaces of things, and is intense but of little amount; in galvanism, it penetrates into the inner atoms, and is more distinguished for amount or quantity than intensity. The difference between them may be illustrated by reference to heat; the flame of the blowpipe has intensity, and will melt, in an instant, a particle of metal, but it has no quantity, and will not produce anything like the effects of a furnace, although at a lower temperature. In the latter case, we have quantity or amount of force, in the former, intensity. It is practicable to unite these conditions, for if we drive a furnace by bellows, or convert it into a blast furnace, we do not diminish the quantity, whilst the intensity is increased. So, in galvanic arrangements, we are capable of generating amount or intensity at will, and approximating or separating their effects from those of the machine. Whenever the plates of the battery are enlarged, and the fluid increased in activity, amount of galvanism is procured; on the other hand, if the plates are small and very numerous, galvanism

of intensity or tension is obtained, which may closely resemble frictional electricity.

*Galvanism is electricity produced by chemical action*; it takes place in every chemical change, but to be sensible of its presence, it is necessary to introduce, among the bodies undergoing this change, conductors capable of conveying the galvanic influence, so that we may apply the tests of its presence. The most common method of generating galvanism is by immersing a plate of zinc and of copper into a very feeble solution of sulphuric acid and water. We may employ the solution so diluted, that it exerts no action upon either metal. If, now, the metallic plates be partially immersed, and brought within a tenth of an inch of each other at their lower ends, and made to touch above, molecular action occurs in the fluid, minute bubbles of gas rise from the copper, and galvanic disturbance takes place. This arrangement constitutes the *simple galvanic circle*, and of such parts, variously modified, the most powerful batteries are constituted.

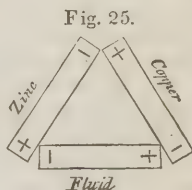
The simplest variation from this original circle, is where the metals, instead of being made directly to touch, can be put in contact or separated by means of two copper wires, one of which is soldered to the zinc, and the other to the copper. The figure may convey a



clear idea of such a circle (Fig. 24) which consists of a common tumbler about half filled with the dilute sulphuric acid, containing *Z* a zinc plate, *C* a copper plate; and *p p'* are the wires called *poles*, proceeding from the metals. The wire of the zinc is called the — or negative pole, the wire of the copper the + or positive pole. The arrows are employed to indicate the supposed course of the galvanic influence or current, from the positive to the negative side.

*Theory of the Circle.*—A little examination will show us that this is none other than an arrangement for the production of internal or molecular electricity. In the first place, it is stated, that the dilute acid would not have acted upon the zinc, without contact of the metals, but if the solution were stronger, the action occurs without this condition, and the reason is, that the acidulated fluid is then itself a fair conductor. The action of which we speak, is the union of the zinc with one of the components of the water, oxygen, the other component, hydrogen, rising at the copper surface, in the state of gas. In the circle, there is, therefore, something present, which produces molecular disturbance, a disturbance analogous to that of heat on the tourmaline, or fric-

tion on glass. This something is the chemical affinity of zinc for a component of water, oxygen. If we investigate the electrical states of the plates, we find that the zinc plate is  $+$  or positive, the copper plate  $-$  or negative, and the wires at their ends also  $+$  and  $-$ , but in a state the reverse of that of the immersed end of either metal. Each metal and wire may, therefore, be compared to a magnet, and the intervening fluid to another; in each case there is a line of particles so arranged as to have their  $+$  ends in one direction, and their  $-$  ends in another. The three are in connection by dissimilar or attractive poles, and they are also distinct in their electrical relations. In Fig. 25, this state is represented; the part of the arrangement represented by the zinc, is one of the magnets, the atoms of which are polarized in such a way that the  $+$  end is in the fluid, and in contact to the  $-$  end of the magnetic arrangement representing the fluid, the positive end of which lies in contact with the copper. The copper is the third polar arrangement, its immersed end being  $-$  and the opposite extremity  $+$ , where it comes in contact with the unlike pole of the zinc. This polarization affects every atom, and occurs only so long as action takes place in the fluid. It is accompanied with a vibratory affection of the ether, and the propagation of a wave, which, in a good conductor, may reach hundreds of miles, as in the electric telegraph. The chemical action sets the electricity in action, and is hence called the electromotive source, and it is to the galvanic circle what mechanical force is to the common machine. If we change the fluid, we may have action in the reverse direction, or none at all; we may render it more powerful, or diminish it to zero.



Let us now consider the reason why action does not occur until contact, when the fluid is feeble. On the immersion of the zinc, its atoms become polarized by the action of the oxygen particles of the water, and in the same way, the water and copper are polarized; but in every case, the condition is *static*; the particles are simply made to arrange themselves conformably to the force present. It is precisely the case of the electrical machine with both the prime conductor and rubber insulated. A few turns produce the polarization of the entire apparatus, one end becomes  $+$  and the other  $-$ , and no further action can be obtained; but if we now connect the two conductors by a metallic rod, equilibrium ensues, and the excited glass disturbs the electricities again. If a rod or chain be made to unite them, the glass will engender electricity without intermission, and the two conductors

will establish an equilibrium at every instant; thus the electrical wave will flow its round incessantly.

*The Cause of the Current.*—These considerations represent the occurrences of the galvanic circle. At first, polar disturbance takes place in virtue of chemical affinity; nothing more can be accomplished; everything comes to rest, for every part of the arrangement is insulated. We now make the metals touch, or connect the conductors, the electrical wave flows, or the forced polar states are neutralized; but as in the turning of the glass, the *electromotive source* is still present and active, new action occurs between a particle of zinc and oxygen, the wave is regenerated, and a second wave flows. If the surfaces be extensive, this apparently intermitting action becomes continuous from the number of particles undergoing union. Several consequences flow from this view of the case.

1st. *The amount of galvanism is directly as the rapidity and extent of chemical action*, for, as the union between the zinc and oxygen is the source of power, the larger the quantity of these combining, the more galvanism. The truth of this position may be directly proved, for if we weigh the zinc plates, and measure, by its effects, the galvanism, we find that the zinc is changed rigorously in proportion to the galvanism.

2d. *The power of a galvanic arrangement is measurably dependent upon the facility with which the chemical union of the zinc and oxygen occurs.* Hence, whatever assists the chemical action, increases the power of the circle. For this reason, in the common arrangement, sulphuric acid is added to the water; it does not undergo decomposition itself, or participate in the electromotive power, but it dissolves the oxide of zinc, formed by the union of oxygen and zinc, and which, being an insoluble non-conductor, would arrest the excitement. The sulphuric acid removes each atom of this compound, forming the soluble sulphate of oxide of zinc, which may be afterwards procured from the solution. Thus the acid acts in keeping the metallic surface of the zinc pure, and enabling new atoms of oxygen to act on it. A great improvement has been, of late, made in this part of the galvanic apparatus. If the zinc be amalgamated with mercury on its surface, it is presented in such a state of division, that the oxygen acts more freely, the surface is also kept bright by the action of the sulphuric acid as before, and the zinc is less acted on by a feeble acid before contact. As a portion of mercury in the amalgam delivers up its atom of zinc, it retires into the mass of metal, and combines with another portion, and thus molecule after molecule is presented to the active oxygen, under favorable circumstances, for chemical union.

The amalgamation of zinc is readily accomplished; for this pur-



pose, it is only necessary that the metal be brought in contact with mercury in a saucer, and the surface rubbed with a pledget of linen or cotton, moistened with dilute sulphuric acid, and used to carry the mercury over the acidulated parts. An amalgam of a bright lustre is rapidly formed on the surface, and the process is soon completed; it is only necessary to rub it once, for excess of mercury destroys the cohesion of the zinc. Mr. Smee has also determined, that, by employing silver as the negative metal, with the surface roughened by platinum, the power is increased by the mechanical assistance given to the hydrogen gas in leaving the surface of the metal.

3d. *Another means of increasing galvanic action, is to increase the conducting power of all the parts*—of the fluid, of the zinc, and the other metal. This is a condition pointed out by the analogy we have drawn; the communication between the two prime conductors being made by a thread, equilibrium would not be brought about so rapidly as by a stout wire. To accomplish these indications, it has been found that the metals should be good conductors; silver and gold are superior to copper, and these are the only substances which would be so. The amalgamation of the zinc assists its conducting power. But it is in the fluid that this quality may be most increased; for this purpose, the acid must be strong, and in the battery of Mr. Grove, presently to be described, the sulphuric acid is of considerable strength, and the nitric acid concentrated. It will be remembered that the strong acids are pretty good conductors, whereas water is almost a non-conductor.

There is also a mechanical method of accomplishing this indication. It is apparent, that the nearer the metals are to each other in the fluid, short of contact, the more readily the conduction takes place. The immersed sections are also favorable to the power, by presenting an immense number of points of action. The doubling of the negative element (copper, silver, or platinum), about the positive (zinc), also assists, indeed doubles the action, by causing it to occur on both sides of the zinc. Again, as respects the poles, the shorter and thicker they are, and the better they conduct, the more readily does the change of polarity occur; if they be poor conductors, and of small size, the action will be impeded and even stopped. For this reason, stout copper wire of the shortest convenient length is to be employed. The influence of this part of the apparatus may be readily seen by interposing between the ends of two large copper poles (or electrodes) a secondary wire of small size of platinum, which is an indifferent conductor; it will become red hot, the electric disturbance being propagated so imperfectly, that the force is ex-

pendent on the molecules producing the specific disturbance termed heat.

*The comparative conducting powers* of different metals belong to this part of our subject. Mr. Harris has found that, if similar wires be made to convey an electric discharge of the same intensity, they become unequally heated. The heat, as in the above illustration, arises from the resistance or opposition to the flow of the electricity, and is, therefore, inversely as the conducting power. The following table from him, presents an approximation only, but it undoubtedly gives us something like the order of conducting power, allowing gold and silver a capacity equal to 120.

Silver	evolved	6	degrees	of	heat,	F.,	and	has	120	conducting	power.
Copper	"	6	"	"	"	"	"	"	120	"	"
Gold	"	9	"	"	"	"	"	"	80	"	"
Zinc	"	18	"	"	"	"	"	"	40	"	"
Platinum	"	30	"	"	"	"	"	"	24	"	"
Iron	"	30	"	"	"	"	"	"	24	"	"
Tin	"	36	"	"	"	"	"	"	20	"	"
Lead	"	72	"	"	"	"	"	"	12	"	"

From these numbers we learn that *platinum* has only one-fifth of the conducting power of silver, and perceive the advantage of using the latter, as in Smee's battery, wherever practicable. Indeed, the only reason that platinum has superseded copper and silver in Grove's battery, is in consequence of the action of the nitric acid, which does not affect platinum, but dissolves the others.

M. Pouillet has also determined the conducting powers of the principal bodies for galvanic currents; they are in the following proportion.

Conducting power of	Palladium	-	-	-	-	5791
"	"	Silver	-	-	-	5152
"	"	Gold	-	-	-	3975
"	"	Copper	-	-	-	3838
"	"	Platinum	-	-	-	855
"	"	Bismuth	-	-	-	384
"	"	Brass, from	-	-	-	900
"	"	" to	-	-	-	200
"	"	Cast steel, from	-	-	-	800
"	"	" to	-	-	-	500
"	"	Iron	-	-	-	600
"	"	Mercury	-	-	-	100

He also measured the conducting power of saline solutions, and arrived at the extraordinary conclusion, that a concentrated solution of sulphate of copper has a power, as compared with copper, of one to sixteen millions; sulphate of zinc, also compared with copper, of one to about forty millions. Distilled water

has, according to the same authority, but one four-hundreth of the conducting power of solution of sulphate of copper, or less than one six-thousandth millionth ( $\frac{1}{6.400,000,000}$ ) of that of metallic copper.

No galvanic action is perceptible in those cases where the fluid acts on both metals, for the polar disturbance is twofold, and in opposite directions, thus neutralizing one another in the same way as one magnet, reversed over another, destroys its power. To attain the greatest developement of galvanism, the action must be intense, and solely in one direction; if there be two opposed currents, we gain only their difference—for this reason, copper, which stands at the head of Mr. Harris's list, can seldom be employed in the most powerful batteries from the action of numerous fluids on it. Platinum is rarely affected, and where it is possible, silver, covered with platinum, constitutes the best negative element.

4th. *Of Resistance.*—Any resistance or impediment occurring in a part of the circle, either by the interposition of a bad conductor, lengthening of the polar wires, or otherwise, affects every part of the apparatus simultaneously. The three supposititious magnets, the two representing the metals, and the third representing the fluid, are equally balanced, and of the same power; if, so long as action takes place, we change either of them, we affect the whole. If the exciting fluid be enfeebled by the separation of the sulphuric acid, the action fails, and is, finally, reduced to nothing. This was the great difficulty with the old batteries of copper and zinc. They could only be charged with feeble acid, and this rapidly disappeared, being converted into sulphate of zinc by combining with the oxide of zinc; and as the amount of acid diminished, the power of the instrument failed, and, in a few minutes, came to an end. To obtain quantity of galvanism, the batteries of Wollaston, Cruickshanks, Children and Hare, were made on an immense scale, offering hundreds of square feet of metallic surface, but they acted only for a short time; and, after a few trials, the metal had to be taken out and scrubbed bright to make them again active.

The greatest improvements made of late in galvanism, are in the construction of portable instruments, possessing great power, or the quality of continuing in activity during a long period. To the former, belongs *Grove's battery*, and to the latter, *Daniell's constant battery*, both of which will be presently described. In the first, the action is maintained for a long time, and by the violence of the chemical changes (there being two fluids polarizing by their action the molecules in the same direction), it is in great amount; in the latter, the object is to keep the action steady, by restoring a fresh particle of sulphuric acid for every one that is removed

by combination, so as to keep the fluid of equal acidity throughout the time of its employment, which may be prolonged for weeks.

*Ohm's Researches.*—Professor Ohm has studied the conditions necessary to the development of power in the galvanic apparatus, and reduced them to mathematical propositions. They are as follows:

1. The electromotive force varies with the number of the fluids and metals, and with their chemical nature, but does not depend on their amount.

2. The resistance to the galvanic force is directly proportional to the distance between the immersed portions of the plates, the resistance of the fluid itself, and the length of the polar wires—and inversely proportional to the immersed surface of the plates, and the section or thickness of the wires.

3. Therefore, the force of the current is equal to the electromotive force divided by the sum of the resistances.

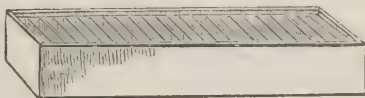
*Effects of the Simple Circle.*—By means of a single circle, we are enabled to produce a variety of electrical effects. By breaking the contact between the polar wires, the electrical spark may be seen, and there is this remarkable difference between the spark of the galvanic arrangement and the electrical machine, that it has scarcely any striking distance even in powerful batteries. If the poles be applied to the tongue, one being placed above and the other below, a slight shock, accompanied with a metallic taste, is perceived. By means of the electroscope, we also discover the presence of electrical disturbance. There is an additional test of great value. It has been known for many years, that a stroke of lightning occasionally destroyed the polarity of the magnetic needle, and Ørsted, in 1819, showed that, when an electrified wire was placed near a magnetic needle, it was disturbed from its true position—hence, this change in direction has become a test of electrical disturbance, and especially in galvanism, which is, therefore, associated with common electricity, in this respect, as well as in the foregoing. It has also been shown, that heat is often produced by electricity, and this is strikingly the case in galvanism, heat being developed in great amount wherever the surface of the immersed metals is large, and the exciting fluid of great activity.

**GALVANIC BATTERIES.**—The simple circle may satisfy us that galvanism and electricity are the same force, but if we wish to observe the properties of galvanism, it is necessary to combine a number of circles, or, in other words, to employ the battery. In the present day, Grove's battery is preferred, but Smee's and Daniell's constant battery are often useful. Of the old batteries, it may be enough to say that they were cumbrous and expensive,



and consisted of pairs of zinc and copper plates fastened into a square wooden trough, into which the active fluid was poured, as in Fig. 26. The zinc plates were all on one side, and the copper on the other, so that each cell contained a copper and zinc plate; the pairs being separated from each other by the fluid. From the last metals, the polar wires proceeded. In batteries intended to generate a large quantity of galvanism, the plates were

Fig. 26.



very large, and either one or very few; when tension or intensity was desired, the plates were small but numerous, amounting, in some experiments, to many thousands. The most important modern instruments are described in the following paragraphs.

The *voltaic pile*, which was the first battery invented, consisted of square pieces of copper and zinc, arranged in pairs, and the pairs were separated by pieces of cloth, moistened with salt and water.

*Grove's Battery.*—This instrument is particularly remarkable for the great amount of heat it sets in motion, even when the resistance is moderate. When the number of circles or pairs exceeds twelve, it also exhibits considerable intensity. It is portable, and continues in powerful action for half an hour or more, and in considerable activity for two days. Hence, it is preferred for general purposes to all modern batteries.

The circle or pair, Fig. 27, consists of two metals and two fluids, the latter separated from one another by a porous vessel of unglazed earthenware. The metals are amalgamated zinc for the positive element, and platinum for the negative; the poles are of copper usually. The fluids are diluted sulphuric acid, and strong nitric acid. The circle is usually arranged in glazed earthenware jars, or stout glass tumblers, the zinc being cast into cylinders with a branch for the purpose of connecting with the platinum pole of the adjoining pair. The cylinder of zinc is placed in the jar, and within this the porous cylindrical vessel, closed below, but open above, and furnished with a flange to suspend it in the zinc; in the centre of this is the platinum connected with the zinc of the next jar. The sulphuric acid is placed in the outer vessel, and the nitric acid in the porous cylinder. In the bat-

Fig. 27.



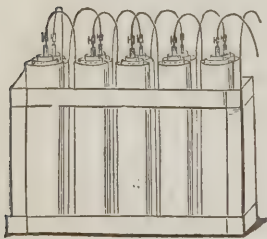


tery, the jars are placed side by side in one, two or more rows, and connected in the order indicated, the zinc of one with the platinum of the other, the series being uniform throughout, and not anywhere reversed. For if, in any case, the zinc of two cups be united, or two of the platina strips, the order is broken and the battery becomes powerless. The union is commonly made by soldering the platinum, which is usually a strip of one half to one inch wide, and of the length of the porous cylinder, to the branch of the zinc of the adjoining pair. From the last zinc and copper, proceed the poles or electrodes. The size of the jars and zinc cylinders, will depend upon the quantity of galvanism required; but pint vessels, with the metals in proportion, are commonly selected. Professor Bunsen has modified this battery, by introducing the hard carbon of the gas houses in the place of the platinum. This is called Bunsen's battery.

The electromotive source in this battery is the oxydation of zinc by the decomposition of water, but the hydrogen of the water, instead of being liberated at the platinum surface, decomposes the nitric acid, and again forms water with a portion of its oxygen, whilst the gaseous nitrous oxide is liberated in red fumes of a suffocating odor. By this reunion, the polarity of the whole arrangement is assisted, the water being reformed. The sulphuric acid employed, may be stronger than that formerly used. Fifty pairs produce the most brilliant results of ignition and chemical change, but very striking effects may be obtained with twelve.

*Daniell's constant Battery.*—The circle in this case consists of two metals, copper and zinc; and two fluids, dilute sulphuric acid and solution of sulphate of copper, (blue vitriol;) these are separated by a porous earthenware cylinder

Fig. 28.



by a glass tube, closed below with bladder. The circle is arranged as follows—the copper is made of the figure of a jar, with a projecting rod or wire, by which it may be put in connection with the zinc of the adjoining pair; it contains the copper solution; centrally the porous vessel is situated; this is nearly filled with dilute sulphuric acid, and contains a rod of amalgamated zinc, which bears an upright arm or offset, to place it in communication with the copper cup

of the next circle. The communicating rods are usually furnished with binding screws, whereby the connection can be readily made between the pairs.

In this apparatus, the action of oxygen is, as before, the active principle, but the hydrogen is not evolved by the copper surface, for as soon as it encounters the sulphate of copper, chemical decomposition occurs, the copper is set free, its oxygen unites with the hydrogen to form water, and the sulphuric acid entering the zinc cell, serves to restore the strength of the acid there. Hence, for every atom of acid which is removed, by uniting with the oxide of zinc, formed by oxidation, there is an atom restored by the decomposing action of the hydrogen on the sulphate of copper. Therefore, the strength of the sulphuric acid being rigorously maintained, the action is sustained, and would be absolutely constant, if the zinc were not dissolved. With a thick zinc rod, the action may be prolonged for weeks. This battery would be of use for medical purposes, but is now partially superseded by the *electrotome*. It may, however, be recommended as the source of power in this machine. The principal use of Daniell's battery is, in effecting chemical changes which require galvanism of little quantity, but of tension to act for a long time. Figure 28 represents this battery.

*Smee's Battery*.—This variety can scarcely be called a battery, for the circles are ordinarily employed alone. Its chief use is in electro-casting of various kinds, and it is now used extensively in the arts. The circle consists of two stout plates of amalgamated zinc, placed parallel to each other, with a thin sheet of platinized silver between them. The plates are arranged close together, and have strips of wood between them above, and corks below, to secure them in their places. The upper pieces of wood also serve to suspend the plates from the sides of a glass or earthenware jar. The platinized silver carries an upright wire with a binding screw to enable the operator to connect it with the zinc of the adjoining pair, or to sustain the polar wire. The two zinc plates are held firmly together, outside the wood, by a clamp of brass, which also puts them in electrical contact; one of them carries a binding screw for the same purposes as that of the silver. The active fluid is dilute sulphuric acid, and the cell is a glass tumbler, usually of a quart size.

Other interesting combinations exist, which are, however, of no practical value. Professor Grove invented a gas battery, consisting of tubes, containing hydrogen and oxygen, the electromotive source of which was the union of these bodies, by means of spongy platinum. A feeble galvanic action may also be obtained by piling slices of brain and muscle in a regular succession, and keeping the arrangement moist.

**GALVANIC EFFECTS.**—When a powerful Grove's battery is employed, the effects are very striking; they are chiefly cases of ignition, the production of light, shocks, and chemical decompo-

sition. But by using a feeble battery, or even a simple circle, the phenomena of induction may be produced, which are the most remarkable effects of this agent. The action on the human body will be considered under the section on **ANIMAL GALVANISM**. One of the most important applications of the force is in the casting of metals, or the electrotype. We shall consider these effects in a few paragraphs.

*The Deflagrating Power.*—When the polar wires of a powerful Grove's battery are gently separated, an intensely brilliant interval is perceived, which consists of the action of the galvanic force on the particles of non-conducting air and the metal. The spark or luminous interval is of different colors, according to the nature of the metals, being green between two copper wires, bluish green between gold, whitish blue when one of the poles terminates in a cup of mercury, and the other nearly touches its surface. If gold, silver or other foil be placed between the poles, it is rapidly volatilized. Iron wire burns with brilliant scintillations. A thin strip of platinum being adjusted to the poles, becomes white hot, throwing out an intense white light.

If the platinum be very fine, it may be heated by a simple circle, or at a considerable distance by a battery; hence it has been made use of as a means of exploding gunpowder in blasting, and for military purposes. We believe the credit of having first proposed this means of blasting belongs to Professor Hare. By adopting it in mining operations and extensive undertakings, many accidents might be avoided, and better results obtained on a large scale. For this purpose, the gunpowder is enclosed in a suitable canister, through which pass two copper wires, insulated from the metal by a coating of silk, Indian rubber, or other non-conducting body. The wires proceed to the centre of the combustible, and are united at their ends by an exceedingly fine strip of platinum. The polar wires at their battery ends can be put in connection with the apparatus at will, and the moment the galvanic influence acts on them, the platinum is made red hot, and explodes the powder. By this means, a mass of material, amounting to many thousand tons, was removed by a single blast, in the excavations made for the London and Dover railway. Ships may also be blown to pieces at a distance of half a mile and upwards, with a battery on shore, by exploding a water-tight canister, containing several hundred weights of gunpowder, and placed in the channel. This project has, indeed, been looked upon as a means of defence in the case of invasion.

The temperature attainable in a small space by a powerful battery, probably exceeds that which can be obtained in any other way, except perhaps Professor Hare's oxy-hydrogen blowpipe. By this means the most refractory metals are fused, and many, as gold, entirely volatilized.

*The Production of Light.*—If the poles of the battery be made to terminate in conical pieces of hard charcoal, or the carbonaceous substance used as luting for coal gas retorts, there is produced the most intense artificial light. It is white, and surrounded by dazzling irradiations, and may be made of considerable amount, by cautiously separating the points. The separation, when a powerful battery is used, may be upwards of an inch, in which case, the flame is arched. But if the points be placed in vacuo, the flame is rectilinear and equally intense. The origin of the flame is not, therefore, due to the combustion of the carbon, but results from the conversion of the electrical disturbance into heat, from resistance to its propagation, and which volatilizes the molecules of carbon, and is analogous to the production of heat in those metals which interrupt the current.

It has been proposed to use this apparatus for illumination. The intensity of the light is such, that an apparatus, set up in an open place, at a suitable elevation, would illuminate many acres of surface; but in cities, the houses are too crowded to allow of its employment, considering the expense necessary in establishing the light. The batteries would have to be rapidly renewed, and demand constant attention to maintain the brilliancy of the arch of flame. Another similar proposition has been made—to use a spiral coil of platinum for illumination, but the light is less intense in this case, demands as much attention, and is equally expensive.

*Chemical Decompositions.*—If the poles of a battery of many pairs, or a battery of intensity, be immersed in acidulated water, the water is decomposed, and if the wires be of platinum, the gases, of which water is composed, are evolved. Numerous solutions are acted on in the same way, especially the iodides of potassium and sodium, and the bromides, chlorides, or oxides of the same bodies. Mr. Faraday has studied this property of the battery with extraordinary success, and arrived at the following general conclusions.

1st. That only particular substances are susceptible of decomposition; such are, conductors containing two elements, as water, which consists of oxygen and hydrogen. To such bodies he has given the name of *electrolytes*; the process of decomposition he terms *electrolysis*; and the poles electrodes. This law is expressed concisely as follows: All compounds, susceptible of primary electrolysis, are of binary composition, containing one atom of each element, and soluble.

2d. Metallic salts, which are soluble in an electrolyte, frequently undergo secondary decomposition. Thus, sulphate of copper dissolved in water, is a metallic salt, containing three elements, (copper, sulphur, and oxygen,) and not electrolyzable, but united



with water, it becomes decomposed. The action commences in the water, which is an electrolyte; the hydrogen and oxygen are separated, but of these the oxygen only is liberated; the free hydrogen, said to be in a nascent state, exerts chemical action on the oxygen of the sulphate of copper, removing it from the metal and reforming water. The copper being no longer oxidized, cannot unite with sulphuric acid, and is deposited on the surface of the negative pole. The same is true for metallic iodides, chlorides, cyanides, and bromides, dissolved in suitable solutions, and for metallic salts generally. When alkaline salts are employed, the acid is found at the positive pole, and the alkali at the negative, hydrogen being incapable of reducing the alkaline metals.

3d. The decomposition is perfectly definite. The same current passing through different electrolytes for the same space of time, will liberate the elements in the rigorous proportion of their atomic weights. Thus, if we submit the electrolytic solutions of iodine, there will always be found the same weight of iodine at the electro-positive, or  $+$  pole, but the weights at the electro-negative pole will be as the equivalents of the metallic bodies. The atomic weights or equivalents will be found in the next division of this work. By way of illustration, it may be remarked, that the atomic weight of water is 9; of iodide of potassium, 165.86; of chloride of sodium, 58.78; and that the same current will decompose in the same time, 9 grains of water, 165.86 grains of iodide of potassium, and 58.78 grains of chloride of sodium. And this is true for every case of primary or secondary decomposition, and proves that the chemical force is a galvanic force, and that the atomic theory, which attributes to the atoms of matter definite weights, rests on the basis of experiment. In these cases, the power (galvanic) which held the atoms in combination, is neutralized by the galvanic current, which operates more powerfully in an opposite direction; they, therefore, obey new polar arrangements opposed to those acting to produce their union. In virtue of the identity of the galvanic force and chemical affinity, Graham has termed the galvanic current—*current affinity*.

¶ So rigid are the chemical relations of the battery, that, if we allow for the losses arising from resistance in the instrument, we shall find, that precisely the same amount of decomposition takes place in the active fluid, and in the decomposing cell. If water, similarly acidulated, be placed in both, there will be decomposed a grain of the fluid for every grain changed in the generating cell. Indeed, in these cases of decomposition, we only modify the galvanic circle, for, instead of its containing three parts, or supposititious magnets, it now has four—the fluid of the generating cell, which has a  $+$  and  $-$  end, the metals and the fluid of the de-



composing cell, which has also its  $+$  and  $-$  end—and we may as conveniently adopt the view that the electromotive force is in one cell, as in the other.

This consideration enables us to understand some points, which are almost in dispute among electricians. It was formerly conceived, that the poles or electrodes acted as centres of attraction, and that an atom of oxygen was drawn through the thickness of the decomposing fluid by their action. This supposition is unnecessary, for all the action takes place at the surface of the electrodes, which may be points or large surfaces, metallic, solid, or fluid, with equal indifference. The polar states of the electrodes are communicated by induction to each particle of the intervening fluid; if this be water, the compound molecules arrange themselves with all their oxygen particles turned towards the positive pole, and all their hydrogen towards the negative pole or surface. The fluid magnet is thus formed, and remains stationary, if the force of the electrodes be less, or equal to the chemical attraction existing between particle and particle of the liquid; but if it be greater, the ultimate molecules of the line are attracted to the poles, unite with it if their chemical nature permits, or are liberated, if there be no chemical relation. It is to avoid the chemical combination that platinum poles are employed in the place of copper, which is so superior in conducting power. The terminal atoms being liberated, the polar state is restored throughout the fluid, and union occurs along the line of particles, or what Grotthaus calls recombination, takes place particle with particle. The forced or polar state is again reproduced, with a similar result, and thus a succession of waves takes place throughout each line of atoms, and always in the same direction. No disengagement of gas, or other product of change, takes place anywhere but at the electrodes, or where the separated molecules can no longer find atoms to recombine with.

**ELECTRO-CHEMICAL THEORY.**—The views of Davy, termed the electro-chemical theory, were dependent upon the above facts. It has been modified, in recent times, by Ampere and Berzelius, to clear up hypothetic defects, but otherwise the theory has been approved for upwards of half a century. Some exceptions present themselves to it, at present, which may, however, be dissipated by further study. Whether it stand or fall, this theory has contributed so much to the advancement of chemistry, and is so connected with the subject, that traces of it will remain as long as the science is cultivated.

Davy conceived that atoms in the state of rest, have no free electricity, but become excited by contact with certain bodies, and combine in consequence of the attraction arising between the dissimilar electricities of the molecules. He divided matter

into two classes, according to the supposed preference for one or the other electricity. Thus oxygen, chlorine and certain other elements, are always found at the positive pole when their compounds with metals are decomposed; hence their electrical preference is for this part of the arrangement, because they are themselves of a negative electricity under excitement. These bodies were, therefore, termed *Electro-negative* elements, whilst the metals which selected the — pole, were termed *Electro-positive* elements. Upon further examination, it was also found that acids were electro-negative, and the oxides or bases, with which they were combined, were electro-positive. Further experience has shown that the electrical condition is not a property of the matter, but depends upon the element or body with which it is in contact; for iodine is positive to oxygen and chlorine, but negative to all the metals; so mercury is positive to the haloid bodies, and negative to most metals. Of all the elements, oxygen and potassium appear to be the only ones which remain invariably in the same state, in the act of combination oxygen being always electro-negative, and potassium electro-positive. The persistence of a compound often depends upon the intensity of affinity of the elements for different poles.

The following table from Professor Kane, exhibits the electrical relations of the principal elements. The most powerfully negative bodies are placed in the first, and those most positive in the fourth column—substances intermediate in their electrical activity are placed in the central columns. Any substance is positive with respect to those towards which the arrows point, and negative towards those bodies placed in the reverse direction.

TABLE SHOWING THE ELECTRICAL RELATIONS OF THE ELEMENTS TO ONE ANOTHER.

Electro-negative.			Electro-positive.
* <i>Oxygen.</i>	<i>Mercury.</i>	<i>Palladium.</i>	<i>Potassium.</i>
Fluorine.	Chromium.	<i>Silver.</i>	<i>Sodium.</i>
↑ Chlorine.	Vanadium.	<i>Copper.</i>	↑ Lithium.
⚡ Bromine.	Iridium.	<i>Lead.</i>	⚡ Barium.
Iodine.	Rhodium.	<i>Tin.</i>	Strontium.
Sulphur.	Uranium.	<i>Bismuth.</i>	<i>Calcium.</i>
Selenium.	↓ Osmium.	↑ Cobalt.	<i>Magnesium.</i>
Tellurium.	⚡ Platinum.	⚡ Nickel.	Glucinum.
Nitrogen.	Titanium.	<i>Iron.</i>	Yttrium.
Phosphorus.	<i>Gold.</i>	Manganese.	Thorium.
↑ Arsenic.	Molybdenum.	Cadmium.	↑ Aluminum.
⚡ Antimony.	Tungsten.	<i>Zinc.</i>	⚡ Zirconium.
Silicon.	Columbium.	<i>Hydrogen.</i>	Lanthanum.
Boron.		<i>Carbon.</i>	Cerium.

\* The substances in Italics are of the greatest importance to the medical chemist.

In the case of compound bodies, decomposition is accomplished in a secondary manner, and acids, alkalies, and other substances, deposited at the electrodes. Some compounds, altogether incapable of decomposition by galvanism, are still spoken of as consisting of an electro-positive and electro-negative part. The following scheme represents the electric state of the parts of any compound.

<i>Name of substance.</i>	<i>Electro-negative body.</i>	<i>Electro-positive body.</i>
Binary compound -	Haloid constituent -	Metallic radical.
Salt - - - - -	Acid - - - - -	Base.
Organic compound	<div style="display: inline-block; vertical-align: middle;"> <div style="display: inline-block; vertical-align: middle;"> <div style="display: inline-block; vertical-align: middle;">Haloid</div> <div style="display: inline-block; vertical-align: middle;">Compound Haloid</div> </div> <div style="display: inline-block; vertical-align: middle; font-size: 2em;">}</div> </div>	Compound radical. ( <i>Basyle.</i> )

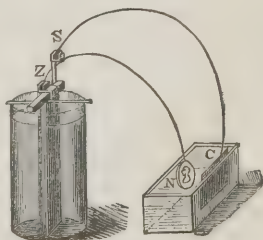
The substances called haloid, are oxygen, chlorine, iodine, bromine, cyanogen, and a few others.

*The Electrotpe.*—The electrotpe is a beautiful application of electro-chemical decomposition. It is intended for the precipitation of metals on surfaces of any kind prepared for the purpose; when gold is employed, the process is sometimes called electro-gilding, when silver, electro-plating. It is also used for obtaining copies of engravings, by depositing copper on the surface of the original; in this case, it is termed electro-engraving. There are other applications for embossing, &c.

For these purposes, Smee's battery, or one circle of his arrangement, is employed. The generating cell is charged with dilute sulphuric acid, and the decomposing cell, which may be a tumbler, tureen, or any similar vessel, contains a solution of the desired metal in an electrolyte. For the precipitation of copper, a concentrated solution of sulphate of copper is employed. To the negative pole of the battery the object to be copied is attached, such parts only as are destined to receive the metallic deposit being exposed, the rest being covered with varnish, wax, or sealing wax, which are non-conductors. To the positive pole is attached a plate of the metal to be precipitated—copper if we desire a copper type, gold if we design gilding the object. Any substance can be coated with metal if its surface be smeared with plumbago, and contact established with the negative pole. When engravings of coins are used,

a coating of plumbago hinders the metal from adhering. The figure (Fig. 29), represents Smee's instrument in action; N C is the decomposing cell; Z is the negative polar wire, to which

Fig. 29.



the coin N is attached; S is the positive polar wire, to which a mass of metal, either copper, gold, silver, &c., according to the operation, is attached at C.

In electro-gilding, a concentrated solution of cyanide of potassium is used as the solvent of the cyanide of gold, and the negative pole contains gold foil. In plating and platinizing, the same solvent is used. In these processes, a little attention is necessary to hinder the metal from being precipitated in the black granular state, which occurs if the solution be too weak. The decomposition in these cases is similar to that described in Daniell's battery, the hydrogen of the water, which is primarily decomposed, causing the separation of the gold or other metal from the cyanide.

**THE INDUCTIVE ACTION OF GALVANISM.**—In the same way that the electrical disturbance of the prime conductor of the machine, or a magnet, is capable of affecting neighboring conductors, so a galvanic current disturbs the polarity of substances situated near its course. If we place a copper wire, coated with varnish, sealing wax, cotton or silk, near the electrodes of a galvanic circle, every time contact is made between the positive and negative poles, an electric wave will pass along the secondary wire. The power of the secondary current will depend upon the thickness and length of the wire, and its approximation to the electrodes. The current of the galvanic battery not having an appreciable striking distance, the wires can be placed very close together, a film of varnish being sufficient to insulate them. The polarities of the secondary wire are the reverse of those of the primary. A third, fourth, fifth, sixth, &c., wire may be employed, and induced currents will arise in all, each being in the inverse direction of the one before it, and the intensity diminishing with the distance. Ribbons of metallic foil, covered with silk, may be substituted for the wires with advantage, as several can be packed together. Induced currents take place in all, but are most powerful in the best conductors.

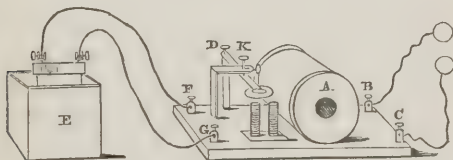
It will be observed, that the current, or molecular change, occurs only at the time of forming and breaking the contact between the electrodes. Hence the use of induced currents for giving shocks, producing decomposition, &c., would be unimportant without some contrivance for breaking and forming the galvanic circle with great rapidity. At first, this was accomplished by terminating one of the electrodes in a piece of metal resembling a file, or the surface of which was roughened by fissures; the other pole being moved over this uneven surface, contact was made and broken every time the wire passed from a projection over a fissure. At these points, a spark passed, and the molecular change or current took place backwards and forwards through

both the primary and secondary wires. When contact was made, the current passed in a given direction, or outwards when broken restoration took place or the wave returned, and thus by rapidly producing impulses of action and reaction, a continuous decomposing effect, or prolonged nervous shock, could be obtained. At the present day, other contrivances, acting on the same principle, and called *rheometers*, are employed. The principal of which is, a small temporary magnet, before which is placed a metallic spring that is drawn to the magnet by attraction at one instant, and then reacts, springing away from it, and thus breaks and establishes the current with immense rapidity.

One of the best instruments for the purpose of putting persons under the influence of rapid shocks of galvanism (electricity), is constructed on the principle before us, and called the *electrotome*, or *vibrating galvano-magnetic machine*. It has superseded the electrical machine, galvanic battery, and magneto-electrical machine, being cheaper, more manageable, and producing effects which may be regulated at will. It can also be intrusted to the care of the patient or his friends, and can scarcely be put out of order.

The *electrotome* (Fig. 30) consists of two parts, a simple cir-

Fig. 30.



cle, usually Smee's, *E*, or Daniell's; but a common cell containing a zinc and copper plate, with dilute sulphuric acid, answers very well; and, secondly, an arrangement of wires for producing the induced current. The second part of the machine consists of two wires of great length; one, of copper, to convey the primary current from the generating battery, and the other, of fine iron wire, to convey the induced current. Both are coated with a thin non-conducting material, usually cotton thread. They are wound in a helix *A*, around a frame of thin card-board, like thread on a spool; the centre of this frame is occupied by a bundle of iron wires, not shown in the figure. One end of the primary wire runs around the small temporary magnet to a small clamp, to which an electrode of the battery can be made fast *G*—the other terminates in the upright *D*, which carries a spring and armature; *F* is a clamp to which the second electrode is attached; it is in



communication with the brass upright which carries the screw *K*. As soon as the current passes, the magnet attracts the armature of *D*, and the connection is broken thereby. The spring, therefore, reacts, and coming up to the screw *K*, the current flows again, attraction occurs again, and these phenomena are repeated many times in a second. Each wave in the primary wire creates a wave in the secondary wire and in the bundle of iron rods, and the latter so far reinforces the secondary current of the wire, as to increase its power to a remarkable extent. It acts with the primary current in this respect, so that all the currents are exalted in tension. The longer the secondary wire, and the more numerous the rods, the higher is the tension of the current.

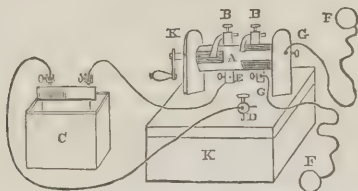
The patient receives a shock from the secondary wire, by holding the ends in either hand; for this purpose, convenient handles *B C*, are provided. The shock of a machine of this kind, set in action by a feeble circle, and consisting of two hundred yards of fine wire, is very intense, transcending many hundred pairs of galvanic plates. The shock can be regulated with the greatest nicety by diminishing the power of the battery, and by diminishing the number of wires, or removing them partly from the centre of the helix. By directing the poles of the secondary wire over different parts of the body, as between the spine and extremities, &c., a current can be sent in any desired direction. The poles may also terminate in plates, and be applied over a considerable surface. Moistening the skin of the part with a strong solution of salt, assists the passage of the current in a great degree.

Dr. Golding Bird seems to have derived great benefit from an electrotome of a thousand yards of fine wire with a peculiar rheometer, such that, the current instead of flowing backwards and forwards, acted only in one direction. With this instrument, a paralytic condition of the body has been produced, amounting, after a few minutes action, to an entire loss of sensation and voluntary motion, the patient being completely enervated. Similar results have been obtained in France, and this modification is worthy of the attention of the profession. I have had one made with eight hundred yards, but whilst it creates a benumbing sensation, and is much less inconvenient to bear than the intermitting current, it has not in healthy persons produced anything but a partial paralysis of the hands and wrists. To observe its effects, currents must be directed from various points of the spine to the parts receiving the nerves, and where the disease of the patient justifies such means, the skin should be previously removed by blisters, and flat polar metals placed over the denuded parts. The poles, in these cases, should be of gold or silver. From European observation, it would appear that the vibrating current produced by the old electrotome creates convulsive action, whilst the constant

current induces paralysis or exalted nervous action, according to its direction.

The rheometer is depicted in the figure; the wooden cylinder *A* is furnished with metallic strips at intervals, which break and

Fig. 31.



form the current by acting on the silver springs *B B*; the box *K* contains the electrotoime.

*Electro-Magnetism.*—If the primary current passes near to a wire of pure (soft) iron, induction occurs among its molecules, and it exhibits a positive and negative pole, or a north and south pole. This is temporary, and exists only so long as the current flows, or the primary wire is at hand. If the wire be of steel, induction takes place slowly, but becomes permanent—in fact, a true magnetic needle is formed. Either of these wires being suspended, will act as a magnetic needle. On the contrary, the polar condition is induced in a wire by the proximity of a permanent or temporary magnet.

If we wind a wire, coated with cotton thread, about a bar, rod, or horse-shoe, of soft iron, and pass a current of electricity along the wire, the iron becomes a magnet, the force of which is dependent on the length of the wire, the battery, and the mass and purity of the iron. Professor Henry put up a temporary or *electro-magnet* of this kind, which could suspend upwards of two tons attached to its armature. The instant the current of the galvanic battery ceases, the iron loses all its power, and these changes can be produced many hundred times in a second. This offers one of the most striking instances of induction on record, and proves that the action takes place at right angles with the force, as well as in the same plane.

It has been shown by M. De la Rive, that if the wires of a small battery be wound into a circle, or prolonged into a helix, the arrangement has the movements of a magnetic needle. Hence a magnetic needle can be made of copper or any conductor, if we provide for the molecular polarities.

*The Earth's Magnetism.*—This brings us to the earth's magnetism, and the reaction of permanent on temporary magnets,

and on galvanic currents, or the subject of Electro-magnetism, which is of great interest, but belongs to Physics rather than to Chemistry. It may suffice for us to allude to the modern theory of the earth's magnetism, which is attributed to thermo-electric currents. The different conducting power of metals (page 27) and other bodies, for heat, is a source of electricity when heat is applied along their points of connection. The surface of the globe consists of land and water, touching at all places; these exercise a very dissimilar conducting power towards the sun's heat, which falls upon them almost incessantly. Thermo-electric, that is to say, electric currents, arise from this source and flow around the earth in curves varying with the arrangement of the land and water, and having two foci, one in the north, in latitude  $70^{\circ} 5' 17''$ , near Hudson's Bay, reached by Sir James Ross in 1831, called the north magnetic pole; the other in the southern hemisphere, called the south magnetic pole. These terrestrial currents induce electrical action in all conductors on the surface, and to discover them, it is only necessary to rotate a disk of copper in the plane of the magnetic equator, to generate electrical currents. The magnetic needle arranges itself north and south, under the inductive influence of the terrestrial currents, placing itself at right angles with their course, and reversed, as regards the earth's magnetic pole, for the so called north pole of the magnetic needle is, in truth, the attracted or south pole, as respects the earth.

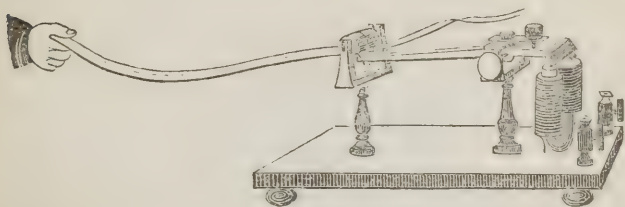
The terrestrial currents are of the highest interest in the chemical and geological history of the earth, as well as in the science of electricity. It has been shown by Mr. Fox, of Cornwall, that in mineral veins there is a constant electrical disturbance, and Becquerel, Cross and Bird have pointed out the influence of such currents in producing the crystalization and segregation of minerals, and the stratification of rocks. Hence the production of metallic accumulations in the earth upon which the existence of the metallurgic act depends, is the result of electric currents engendered by the heat of the sun.

We have no space to devote to a consideration of the numerous cases of the induction of currents, &c., and can only allude to two important instruments, constructed on the principle that a galvanic current induces polarity, viz: the *Magnetic Telegraph*, and the *Galvanometer*.

The *Magnetic Telegraph* of Mr. Morse consists essentially of two parts, a galvanic battery with poles of immense extent, that is, stretching from one city to another, and a temporary or electro-magnet produced by this current. The battery in Baltimore being put in action, the galvanic influence reaches Philadelphia, and there circulating about a large iron horse-shoe, converts it

into an electro-magnet. This now attracts a piece of soft iron (the armature) placed above it, and at the end of which is a lever carrying a pen; thus as the iron armature is drawn down, the pen is struck upwards into a piece of paper, and makes a mark. The paper is made to roll by a machine, and thus presents a new surface every second, for the action of the pen. The figure (32)

Fig. 32.



represents the working portion of this instrument. A message is communicated in the following manner:—The operator at Baltimore, or elsewhere, is provided with a plan by which he proceeds; according to this, the different letters of the alphabet are represented by dots or short strokes, and made by breaking, or continuing for a measured time, the connection of the wire with the battery. Every time the current is broken, the electro-magnet in Philadelphia, or other station, is destroyed, for its action as a magnet depends on the current, hence the pen falls from the paper, but if a new current is now set up, the pen again makes its mark, and it is a dot, a long or short stroke, according as it is more or less continued at the will of the operator at the remote station.

Mr. House has a patent for an exceedingly ingenious machine, which prints the message in large type. A wheel, on the circumference of which are the raised letters of the alphabet, is made to turn, so long as the current between the stations flows, but stops the moment it is broken; at the same time, a piece of paper is pressed against the letter at which the current is stopped, and an impression made which is inked by a simple contrivance.

**GALVANOMETERS.**—There are two instruments employed for the measurement of galvanic, thermo-electric, and other currents. The Galvanometer is of great service where the influence is feeble, and of high tension; the Voltmeter is useful only where the effect is considerable, both as regards quantity and tension, and is employed for the determination of the action of batteries. M. Matteucci has introduced another means of detecting extremely feeble currents, by employing the hind leg of a frog, called by



him the *galvanoscopic frog*; it will be described in the next article on Animal Galvanism.

*The Galvanometer.*—This instrument, in its simplest form, consists of a thick brass wire, bent into a parallelogram, and carrying mercury cups or clamps at the two ends; this encloses a magnetic needle, and is arranged on a stand furnished with a compass card, or a graduated circle to measure the movements of the needle. The instrument of a simple form is represented in Fig. 33.

Fig. 33.



A current of galvanism passing along the wire *N, B, S*, of this instrument, produces an induced action on the needle, which deviates from its magnetic position in direction and extent, according to the nature of the current. Contact is made, with any circle, by placing the polar wires in the cups *C, Z*, which terminate the wire, and which are charged with mercury.

To understand the value of this instrument, and the recent improvements made in its construction, it will be necessary to explain the action of different currents on the needle. If we place a wire, transmitting a current of galvanism above a magnetic needle, it attempts to arrange itself at right angles with the direction of the current, and will do this if it be strong; but it is certain, that, after the power of the current is sufficient to deflect it to this extent, the needle cannot measure any increase in its force. One of the modern improvements is to enable the experimenter to determine the true amount of force by suspending the needle with a fibre of silk, or a thread of glass, and measuring the deflecting power by forcing back the needle to its old position; it is obvious that, in doing this, the silk or glass will be twisted by a force accurately representing the deflecting power, and all that is necessary is, to connect the fibre with an index, traversing a graduated circle, as in Coulomb's torsion electrometer.

But the needle may range to the east or west, and this depends upon the direction of the current. If the galvanic wire be above, and parallel to the needle, the pole next to the negative end of the battery will move westward; if the wire be now placed below, it moves eastward; if on either side, the end of the needle will be elevated or depressed. If the current be now reversed, the needle moves to the westward, &c. The parallelogram of wire, there-



fore, assists the action of the current, for the force which acts on the upper side to deflect the needle to the west, when the current flows from the positive towards the negative pole, also accomplishes a similar effect, when flowing on the lower wire. Hence another improvement of the galvanometer is in the reduplication of the wire, and, instead of one turn, a great number are made, the metal being covered with cotton or varnish to insulate it. The effect is multiplied on the needle, and the instrument made much more sensitive.

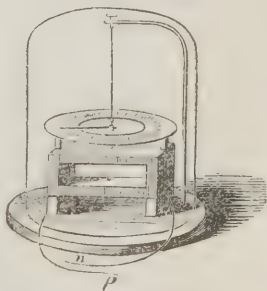
A third improvement consists in employing two magnetic needles of the same power, and suspended in a reversed direction. When the two are accurately compensated, they lose their directive power north and south, and remain in any position they may be placed; under such circumstances, they are said to be *Astatic*. This arrangement is seen in Fig. 34. In this way, the power of the earth's attraction, which counteracts, in some degree, the deflecting force of the current, is neutralized, and the movements are larger and more free. The astatic needles should be suspended by a glass thread in such a manner as to have one situated above the wire of the coil, and the other between its folds; for this purpose a small space is left in the wires to allow the axis carrying the magnets to pass. The axis is of wood, or ivory. A graduated circle is usually placed under the upper needle.

Fig. 34.



The machine being covered with a glass jar, becomes the improved galvanometer. When used, the poles of the battery, thermo-electric pair, or other electro-motive arrangement, are brought in contact with the terminal wires of the coil *n. p*; the current now passes throughout the coil, and thus affects the needle by induction. This delicate instrument was employed by Melloni and Forbes in their researches on Heat, already alluded to. By means of it, with a thermo-electric pair of brass and tinned iron wire, I was enabled to discover the law regulating the temperature of plants.\* By introducing the point of the pair in the various organs of plants, and measuring their

Fig. 35.

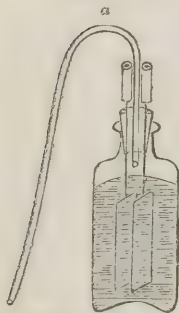


\* London, Edinburgh and Dublin Philosophical Journal. July, 1842

temperature by the deflecting power of the current, on a delicate galvanometer, I found that the flowers developed the greatest amount of heat, and that the temperature of the vegetable depended upon the ratio of the chemical action going on in a part, and the drying power of the air; so that the function of transpiration in them is equivalent to perspiration in animals, and depends in its variable amount on the hygrometric states of the atmosphere.

*The Voltameter.*—This is an instrument invented by Professor Faraday for the purpose of determining the action of a battery, by its power to decompose water slightly acidulated with sulphuric acid. The gases are both collected and measured in a glass tube, graduated in cubic inches and decimal parts. The form employed is various, but the following is simple and convenient. Take a stout glass bottle of eight ounces capacity, and

Fig. 36.



a wide mouth (Fig. 36); adjust a wooden stopper to it, perforated so as to allow the bent tube *a* to pass through it. The tube is sustained in its place by cement or otherwise, and reaches to the upper part of the bottle. In the vessel are introduced the two platinum electrodes to decompose the fluid; these connect by varnished wires with the wooden cap, terminating on the upper surface in separate mercury cups.

The voltameter is charged with water slightly acidulated with sulphuric acid. In using this instrument, we bring the positive and negative poles of the battery to the mercury cups, whereby the circuit is completed; the gases of the water, being liberated, pass off along the tube *a*, and are measured in a graduated tube. The power of any two batteries will be as the number of cubic inches of gas produced in equal times.

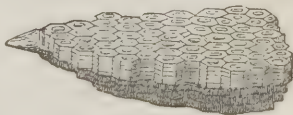
## ANIMAL GALVANISM.

THE extraordinary fact, that there exist several fishes which are capable of producing a shock similar to that of the Leyden jar, has been known for some time. There are five such animals; the electrical Ray or Torpedo (of which there are three varieties, the *Torpedo galvani*, *T. narce* and *T. nobiliana*), inhabiting the Mediterranean Sea; the *Gymnotus electricus*, or electrical eel, found in large ponds in South America, and from four to five feet in length; and the *Silurus electricus*, *Tetrodon electricus* and *Trichiurus electricus*, which are little known.

If the body of either the torpedo or gymnotus be touched; a slight shock is experienced; but if, in the case of the torpedo, we place one hand on the upper side of the thoracic portion of the body, and the other opposite and under the creature, a powerful shock is experienced. In the gymnotus, we touch the head and tail to experience the most powerful action of the animal. Confining ourselves to the torpedo, it will be found that there are certain portions of the thoracic regions more active than others, and upon dissecting the part, we discover a cellular structure, called the electrical organ, where the shocks are evidently produced. If we dissect out this part, leaving only its nerves uninjured, it continues to evolve electricity; and, indeed, does so when altogether removed from the system. The structure of this organ is peculiar and suggestive of a combination of galvanic piles; it is represented in Fig. 37.

Upon a minute inspection of the organ, it is found to consist of a large number of polygonal cells, regularly superimposed in prismatic columns. Each cell appears to consist of a cartilaginous wall, over which ramify branches of nerves, and the centre is occupied by a dense albuminous, and slightly saline fluid, like the white of an egg. The nerves supplying the organ are very large, and correspond to the eighth pair and a large branch of the trifacial. If one of these nerves be irritated, the portion of the organ to which it is distributed produces a current. The nerves of supply terminate in a large lobe of

Fig. 37.



the brain lying in contact with the medulla oblongata, and forming a large portion of the encephalon. An irritant applied to this electrical lobe, or to any portion of the medulla or spinal cord, causes rapid discharges; but this does not occur if the cerebellum, optic lobes, or cerebrum, be touched or even penetrated by a knife. In the gymnotus, the nerves supplying the electrical organs are derived from the dorsal portion of the spinal cord; and in the *Silurus*, from both the medulla oblongata and spine.

By means of the galvanometer we discover that the current producing the shock is from the back to the abdominal side of the fish, or, to speak as an electrician, the dorsal aspect of the organ represents the positive side, and the abdominal the negative side, the current passing from the positive to the negative surface.

The shocks of the animal are under the influence of its instincts, and can be repeated only a few times before the creature becomes disabled. Indeed, in South America, the gymnotus is caught by irritating and causing it to give a number of shocks, after which it becomes enervated and powerless for some time, and may be taken with the hand.

Observe that the electrical power is associated with the development of large nerves, influenced by the will, and capable of so far subduing the nervous power of the animal that it loses energy, is incapable of muscular contraction, and entirely enervated. Secondly, if we separate the organ with its nerves from the body, pinching or irritating the nerves will at first produce electrical currents appreciable by the galvanometer; but this soon ceases, and now the passage of a galvanic current along the nerves arouses the action of the organ again. At the moment of establishing or breaking the galvanic current, the organ responds, but in the interval no disturbance occurs. Finally, the cells, separated from all nervous connection, evolve electricity, when pressed or warmed.

Matteucci has detected a current from the toes to the head in the frog; Aldini, Donne, and others, musculo-cutaneous currents in many animals, and man.

Faraday has shown that a Leyden jar, and indeed a battery, can be intensely charged by the gymnotus; the spark has been seen, needles magnetized, solutions decomposed, and all the phenomena of galvanism and electricity produced. Such observations have multiplied, until no doubt exists on the subject, that the nervous energy of the torpedo is convertible into electricity, if it be not that agent.

Let us now pass to the influence of electricity and galvanism on the bodies of the higher animals. By the action of this agent, partial or complete paralysis and death may be brought about. Involuntary movement, painful sensations, the manifestation of

light, sound, taste and odor also occur, when currents are passed through certain nerves. If a current be directed to the brain by a dissevered nerve in a rabbit, pain is produced and muscular contractions result. Here an influence propagated along a sensory nerve to the encephalon reacts, or is reflected to a motor nerve, operating in the reflex manner which Dr. Marshall Hall has shown to be the case in the human body with the nervous fluid. If a rabbit be killed by a blow on the head, and then subjected to the galvanic current, it is thrown into violent motion every time contact is made or broken, if one of the poles be over the spinal marrow, and the other applied to a muscular surface. If the current pass from the cervical portion of the spinal marrow to the fore legs, they will be convulsed; if from the lumbar portion to the hind legs, these are thrown into action. In short, the best results are obtained when the current runs between the nervous accumulations in the spine and the muscles to which they pass.

Convulsions occur only when the current is broken, not whilst the circle is closed. If we direct the current through portions of the cerebrum or cerebellum, no action occurs, but when it passes through the tubercula quadrigemina, the crura, or the medulla oblongata, violent convulsions occur throughout the entire animal, with signs of suffering. It will be observed, that this is similar to the action on the torpedo, the electrical lobe being situated on the medulla oblongata.

The difference of effect between a direct and reversed current, is worthy of particular consideration; for the demonstration of this we are indebted to the labors of Professor Matteucci of Pisa. The current is said to be *direct* when the positive pole of the battery is placed over the spine or nervous centre, and the negative over the ramifications of the nerve. The reverse position gives us the *inverse* current. Action is greatest when the influence is directed along a specific nerve, and least when it passes across the nerves and muscles. The evidence of pain is much greater at the commencement of the *inverse* current; the muscular contractions most severe at the beginning of the *direct* current; but neither effect takes place during the closed state of the circle.

If we operate on a living animal, these effects lessen with repetition, and become very feeble, but recur after an interval of rest, so that there is an analogy between the reduction of nervous power under the stimulus of galvanism, and the cessation of action in the gymnotus and torpedo. It also appears that the galvanic influence proceeding from the periphery to the spine, is attended with a reflex nervous current from the centre to the periphery in other nerves; or that an electrical current of one nerve can set in motion the nervous fluid of another nerve, in the same way that a galvanic current passing along the polar wires, influ-



ences the electricity of a secondary wire, producing a reversed current therein.

There is another intimate relation between the course of the nervous fluid, and the direction of the galvanic current. If we pass a current of galvanism through two legs of a frog connected by a small portion of the lumbar spine, in such a manner that one pole is in contact with the toes of one leg, and the other with the same portion of the other leg, the current will be direct in one limb, and reversed in the other. It will flow from the periphery in one case, and from the spine externally in the other. Now, after some minutes, we will find that the leg conveying the direct current does not contract when the circle is broken, but the other does so for many minutes longer. From this extraordinary fact, which is true for living and dead animals, Matteucci draws the important conclusion, *that the excitability of a nerve is much more weakened by the passage of the direct (from the spinal marrow to the periphery of the nerve), than by the inverse current.*

Again, he has proved by experiments, that the inverse current, so far from diminishing the excitability of the nerve, exalts it. Thus, if we take the leg and thigh of two frogs, equal in all respects, and pass through one the direct current, contractions of a vigorous kind occur at first, every time the circuit is broken or formed, but these diminish, and are entirely suspended in twenty or thirty minutes; the nervous excitability is now destroyed. But the other leg, in which an inverse current flows, is not so affected; the convulsions estimated in the first second, are not at all stronger than those occurring three or four hours after the current has been flowing—hours after all trace of excitability by the action of this agent has ceased in the limb traversed by the direct current. There is a peculiarity in the contraction which takes place under the influence of the inverse current, after allowing the circuit to remain closed for some time; upon breaking it, *the limb is drawn up for some seconds, and not spasmodically affected, a condition resembling TETANUS, or permanent contraction being produced.*

We hail in these facts, deduced from numerous and accurate experiments, the first principles calculated to guide us in the application of the electrical agent to the treatment of disease. Let the student remember :

“1st. That the contraction excited by the electric current, transmitted along a nerve in the direction of its ramifications, and which we call *direct*, is always more energetic than that which the same current produces when passing along the nerves in the opposite direction.

“2d. The *direct* current weakens, and rapidly destroys the

excitability of a nerve; whilst the passage of the *inverse* current augments it within certain limits."

In respect to the second fact, it is proper to remark that the contraction is stronger after the inverse current has flowed for some time, than at first, whether we excite muscular action by electricity, or the application of any other stimulus, in the dead or in the living subject. Again, if we allow the nerve some repose after the passage of the *direct* current, it recovers part of its excitability, and, under the same circumstances, the excess of excitement produced by the inverse current soon disappears. The power of the muscular contraction is also proportional to the quantity of electricity which excites it, and the feeblest currents are capable of producing it if properly employed. If we exhaust the nervous power of a limb by the direct current, and then allow the inverse current to flow, it will recover its power of contracting, the galvanism serving by its action to bring about a result similar to that of the nervous power itself.

The result produced by the current depends upon the function of the nerve along which it traverses. Passing along the nerves of sensation in the direct manner, pain occurs; in the inverse direction, motion. Passing along the optic nerve, flashes of light are perceived; sounds heard, when directed through the ear; taste experienced, when flowing through the nerves of the tongue. Experiments made by Humboldt, show that currents transmitted through the ganglionic nerves to the heart and intestines, produce muscular movements in these parts, which are remarkably different from those of the ordinary muscles. *The movements are slow to appear, but continue during the closed state of the circle, as well as some time after.* In the muscles of animal life, they appear only at the interruption, and cease on removing the stimulus; but the heart has been seen to pulsate for some time after the galvanic action had ceased.

The influence of a continuous or interrupted current of electricity is also of the first physiological interest. In the cases given, the continuous current was found to destroy nervous power after many minutes when direct, and to exalt it even after hours when reverse. But when interrupted by breaking and forming the communication with rapidity, the nervous power is much more rapidly exhausted, than by the continued application of the direct current. Masson, who first experimented on this subject, succeeded in killing a cat in five minutes by an interrupted current with a small pile, which would have scarcely affected the animal when continuous. In such cases, the interruptions are not extremely rapid, for Pouillet has remarked that, when the interval between the currents is so small as the  $\frac{1}{300}$ th of a second, the effect is similar to that of a continuous current. Matteucci killed

a rabbit in a few seconds by the use of an interrupted current passing from the nape of the neck to the mouth. Weber has also remarked that the pulsations of the heart cease when the interrupted current is made to act on its nerves.

The electrotome, (page 105,) as usually employed, and the magneto-electrical machine, give interrupted currents, and are therefore to be employed with some care. The electrotome, with Dr. Golding Bird's rheometer, gives an interrupted current, but in one direction only. In this case, the first induced current is felt, but not the return current; hence, by its use, the physician can employ an interrupted current in one direction if he desires, and results widely different from those obtained by using an interrupted current in both directions, seem to be obtained.

*Therapeutic Uses of Galvanism.*—The galvanic current from a Cruickshank's battery of fifty pairs of zinc and copper, two and-a-half inches square, charged with salt and water, was formerly employed. In the present day, the electrotome and magneto-electrical machine are almost exclusively employed. These latter are, however, mostly used as contrivances for the production of interrupted currents, but the former may be used for a continuous current by screwing down the armature of the magnet. Cruickshank's battery may be employed for the continuous or interrupted current; this form is, however, objectionable, from the short period during which it is active. For obtaining the continuous current, Daniell's battery is very superior, and much more manageable than it.

Current electricity has been recommended in functional amaurosis and paralysis, in chronic rheumatism, indigestion, asthma, sciatica, neuralgia, nervous deafness, and generally for loss of power in the various parts of the nervous system. It has also been highly spoken of in asphyxia, produced by drowning, suffocation, loss of power in the respiratory muscles, or the heart, or in any other manner. In loss of function of the lungs, brain or other organ from congestion, it has also been recommended especially by Dr. Wilson Philip. Reducing the consideration of the subject to our limits, and discarding the numerous cases which are disputed, we may condense the subject into a few paragraphs.

In *functional paralysis*, arising from want of nervous power, the inverse current from the feet or hands, as the case may be, to the roots of the nerves of supply in the spine, should be used. The contact should be made by broad metallic bands applied to the skin, previously moistened with salt and water, to assist the conducting power, or the connection may be made more complete by introducing acupuncture needles into the part, and bringing the broad polar ends of the electrodes in contact with them. The

induced current of the electrotome or magneto-electrical machine, with Dr. Bird's rheometer, seems to be serviceable, or the current may be rendered nearly continuous by managing the armature with the finger, or screwing it down on the electro-magnet; or a Daniell's battery may be employed. Experience has shown that, in the commencement, the current must be very feeble, and that it is best to interrupt it some thirty times, during a few minutes, and discontinue the application, recurring to it once or twice daily, at the same hours, for several weeks. During the administration, the patient should be sustained in good general health, the food should be nutritious, and liberal in amount, and the affected limbs used, if possible, or excited by friction, warmth and shampooing. The number of recoveries on record, in these cases, are sufficiently great to permit us to expect a favorable issue.

An experiment of Matteucci shows that the function of the muscles of a part may be recovered, by the use of galvanism, a long time after the nerves of supply have been cut, whereas it is soon lost if no such means be employed. Divide the two sciatic nerves of a living frog, allow one limb to remain quiet for ten, fifteen, or twenty days, and submit the other, two or three times a day, to the action of a current—it will be found that the latter contracts, whilst the other leg ceases altogether to be influenced by the galvanic current.

*Loss of Nervous Power.*—In the numerous cases falling under this general head, the nearly continuous and inverse current may be expected to accomplish something when assisted with proper hygienic treatment. As in the case of paralysis, it will be advisable to interrupt the current occasionally, and adopt the other adjuvants indicated.

*Increase of Nervous Power.*—Tetanus, hydrophobia, epilepsy, catalepsy, convulsions, and neuralgias, fall under this head. In tetanus, we have a continued exaltation of nervous power; this is to be treated by the partially *continuous direct* current, the operation of which is to diminish the nervous power. The electrodes are to be placed between the muscles affected, and the roots of their nerves. By this means, a patient laboring under traumatic tetanus, was enabled to open his mouth, and use the affected muscles. A cure was not effected, nor is it to be expected in that variety of the disease arising from wounds; but it would be culpable to discard a remedial means in such cases, even though it may not cure, if it has been found to alleviate suffering. In hydrophobia, the current cannot be readily employed, but if the opportunity offers, it should be continuous and direct. In epilepsy, catalepsy, convulsions, and neuralgia, it should also be almost continuous and direct.

Experiments on frogs, thrown into convulsions and tetanized



by narcotics, have shown that a continued direct current will overcome these states.

In *Asphyxia*, including congestions of the brain and lungs, the electrical current may be used for the purpose of arousing the muscles of respiration and the heart. For this purpose it should be an inverse current, often interrupted. One pole should be situated high up in the neck, to be as near as possible to the medulla oblongata; it should also be brought in contact with the nerves by an incision into the parts, and the other pole must be brought by an incision in contact with the diaphragm, or by acupuncture needles with the respiratory muscles. In the interruptions, which should be frequent, it would be well to bring the pole in contact with all these parts in succession. M. Bourgeois has suggested driving needles into the heart also. In these cases the electrotoime is to be preferred.

In *Aneurism*.—Dr. Apjohn suggested, and M. Petrequin of Lyons has practised, the introduction of needles into the aneurismal sac, put in connection with the poles of a battery, for the purpose of coagulating the blood in the part, and causing the removal of the tumor without ligature.

M. Petrequin, with several Italian surgeons, have had considerable success in this operation. Popliteal and brachial aneurisms of considerable size, as well as varices, have been completely obliterated by the action of a current from a pile of twenty copper and zinc pairs, two inches square, separated by pieces of cloth moistened with solution of common salt, and used for fifteen minutes. M. Petrequin lays down certain rules essential to success: the force of the circulation should be diminished by compressing the vessels of supply, and by diet and other means before the operation—the needles are to be varnished over the parts which are in contact with the integuments and coats of the aneurism, otherwise considerable inflammation arises—four or more needles are to be employed in large aneurisms, and the shocks should be sent through in every direction; the needles are to be plunged obliquely, so that the points approach one another, but do not touch. There is no doubt that, with proper management, this method will be found to supersede the operation of tying the artery in two-thirds of the cases of aneurism. In the cases given, it uniformly succeeded, and the cure was perfect in about eight days.

*Other Applications*.—Prevost and Dumas have proposed galvanism for the destruction of the *fusible calculus* in the bladder. They introduced such a stone into the bladder of a dog, and brought the poles of a Cruickshank battery of one hundred and twenty pairs to bear upon it, in the presence of a large quantity of water—it was entirely disintegrated, being reduced to powder,



which was voided. The poles were introduced in a canula by the urethra. In *asthma* and *dyspepsia*, Dr. W. Philip used a continuous current; in these cases, the positive pole was placed over the nape of the neck, and the negative to the pit of the stomach.

In chronic cases, the plan recommended by Dr. Mansford may be found useful. Two plates, one of zinc and the other of silver, of a size and shape depending on the part and gravity of the disease, are provided, and union established between them by a stout silver wire. The plates are adjusted over the roots of the nerves, and the parts affected. To secure their action, both parts are made bare by a blister, and pieces of moistened wash leather placed between the plates and body; the plates are also kept in place by strips of adhesive plaster. The zinc plate should be examined several times a day to remove the oxide by scraping. We should also imagine that frequent interruptions would be serviceable. This plan is empirical, but has been found useful in the hands of Dr. Mansford in epilepsy, and valuable by Dr. Thomas Harris, of Philadelphia, in several cases of neuralgia. The position of the zinc or positive pole must depend on the direction we wish to give the current. Dr. Golding Bird proposes a similar plan for the cauterization of the parts, from which it is to be inferred that the action is severe. He employs discs of metal of the size of a cent piece, and causes the zinc to be frequently cleaned.

#### THE PROPER GALVANISM OF ANIMALS.

In considering the electro-motive source in galvanism, we assumed the position that in every case of chemical action, electricity is produced, and its presence may be made evident, whenever conductors are present to convey the influence. By direct experiment, Lagave, Buntzen, Prevost and Dumas, Kæmtz and others, have demonstrated that the reaction of blood, saline fluids, and various organic matters, on flesh, nervous matter, brain and the animal solids, produces a galvanic current. Lagave formed a battery of alternate slices of brain and muscle, and conceived that animal electricity arose from the contact of these tissues in all parts of the body, a view somewhat similar to that of Galvani and Aldini. The chemical changes which incessantly take place in the muscles and tissues of animals, produce galvanic disturbance, which has been detected over the whole body by Pfaff, Ahrens and Humboldt, by the divergence of the gold leaves of the electrometer, when the subject of experiment was insulated; this is called *the proper electricity of the animal*.

Valli, Donne and Matteucci have found that when the interior of a muscle and the skin, or its cellular envelope, were ex-

amined by a delicate galvanoscope, a current of galvanism was always found flowing from within outwardly. Moreover, the intensity and amount of this current depend on the vigor of the animal, and the supply of blood to the part; when blood was partially absent, the current became very feeble. Here, then, we have a demonstration of a galvanic current existing at all times in the muscular tissues, and arising from the changes taking place in the blood and tissue during the functions of nutrition and change, and subject to increase or diminution according to the supply of blood. This is called the *muscular current of animals*. The nervous system has nothing to do with it, for so long as action takes place between the blood and muscle, the current flows, whether the nerves be divided or entire.

It is so far apparent, that a muscular battery may be made by connecting a number of frogs' thighs, in such a manner that the exterior portions of the muscles of one shall be in contact with the interior parts of the next. This may be moistened with a saline mixture or water, and will produce a considerable deviation in the galvanometer, when the ends are brought in contact. It is depicted in Fig. 38. *A* is the positive, and *R* the negative end, and the arrow indicates the direction of the current.

Fig. 38.



For the detection of the galvanic currents in animals, Galvani, Aldini and Matteucci have introduced the galvanoscopic frog. This consists of a hind limb of a frog, deprived of its skin, with the muscles and bone of the thigh removed, but the crural nerve left entire, and exposed above the knee-joint. The prepared leg may be kept in a glass tube, with the nerve exposed, as in Fig. 39. It will be found that when the nerve is placed on any substance in which galvanic action is occurring, the remaining muscles of the fore-leg and toes will be thrown into contractions, and thus indicate a degree of electrical disturbance too feeble to affect the common electroscopes.

Fig. 39.



By means of the galvanoscopic frog, it has been proved that electrical currents are produced in all the muscular structures of the body; but such currents have not been discovered in the nerves or glands. Moreover, whatever substances or actions reduce the vigor of the muscular system, or remove the quantity of blood circulating therein, diminish the force of the current; and, on the contrary, whatever increases its activity, seems to develop a greater electrical action. The galvanoscopic frog is affected, whether the muscle be a part of a living animal, or of one recently killed, and especially when the muscle is in the act of contraction.

Again, if a current of galvanism be passed along a nerve, so as to produce muscular contractions in a living or dead animal, the galvanoscopic frog responds to the disturbance. Nay, more, the current induced in one frog may be made to act on a second, third and fourth limb, so that a series of induced currents of the second, third and fourth order, are produced precisely in the same way as in a compound helix of wires. The induced currents in these cases do not arise from any direct action of the electrical agent employed in producing the primary effect, for we may surround the nerve of the galvanoscopic frog with varnish or other insulating materials, and yet they occur. Induction occurs, whatever be the cause of muscular contraction, whether the will, mechanical or chemical stimulants, or electricity. But there does not appear to be an induced current when the nerve of the frog lies upon the brain or another nerve, whatever be the measures taken to irritate these parts.

If we enter into the consideration of the phenomena of induced contractions, we are led to suspect the existence of a galvanic current in the muscles of animals. We find nearly all the known facts conform to this hypothesis. The amount of the current is so small, and the conductors in which it takes place, so indifferent, that we may fail, in determining some points, more from want of delicate tests than from any distinction between the agents. If we trust to analogy, the hypothesis gathers greater strength, for, anatomically considered, the structure of muscles, and the electrical organs of the torpedo and gymnotus, are of the same type, and differ mostly in the size of the cells and the distribution of nerves. The muscles of organic life are remarkably similar, since these receive the same nerves as the electrical organs, as well as possess a similar structure.

As galvanism, or any stimulant addressed to the nerves, produces muscular contractions with the evolution of a force, so the same means arouse the organs of the torpedo, and develop an agent identical with electricity. The galvanic action also produces pain, increases the secretions, or induces contractions; it is capable of

exalting the nervous power or annihilating it, of causing tetanus, convulsions, or complete prostration. Hence, whatever may be our views of the nervous power, it is apparent that within narrow limits, its place may be temporarily occupied by the galvanic current, and the results produced will be so similar that no one can distinguish between them. The organic nervous power does not act more rapidly, cannot produce more active movements, nor induce any phenomena of the body different from those brought about by galvanism for a brief period. In the electrical fishes, the nervous power is convertible into galvanism. There are the same laws of induction common to both, and the same necessity for chemical action to develop both. Thus, these agents appear to be, if not identical, modifications of the same force, and by no means so dissimilar as magnetism and electricity appeared to be only a few years ago.

All experimenters have failed to obtain an induced current in a magnetic needle, or galvanoscopic frog, from a nerve or the brain. But this does not prove that a current does not pass in them, for we fail even when the nerve is made to transmit galvanism, although vigorous contractions are occurring in the muscles. There is another exception taken to the view, that the nervous power and galvanism are identical—that tying a nerve destroys its capacity to transmit a nervous current. This is to be expected, if we remember that the nerve is an indifferent conductor, which may, like a fluid, convey the force only by a series of decompositions and recompositions among its molecules, and may, therefore, lose its connection by the action of the ligature. It is said that, under the same circumstances, it can transmit an electrical current which has a striking distance; but Matteucci has shown that it also impedes a galvanic current of very low intensity.

This capital objection has, therefore, been removed, and something like a demonstration of the existence of a current passing between the stomach and liver, has been made by Matteucci. It will be remembered that the secretion of the stomach is acid, and that of the liver alkaline, and this has induced many theorists to surmise the existence of such a current. The experimental proof is as follows: a plate of platinum was introduced into the stomach of a rabbit, and another placed on the skin over the liver; when these were put in contact by a wire connected with a galvanometer, a considerable current was detected, which deflected the needle  $20^{\circ}$ . This current was found to be connected with the integrity of the pneumogastric nerve, for, on severing it, the deflection became only  $3^{\circ}$ , and it was entirely connected with the brain, for, on decapitation, it ceased altogether.

As we know that chemical action is always occurring in the muscular structure, and Matteucci has shown the muscular or galvanic current derived therefrom to be more intense than that



common to the system, and called the proper electricity of the animal, it is apparent that it must accomplish something. A new theory of muscular action has been based on this fact. It is supposed that the galvanism generated in the cells of the muscular tissue, causes them to repel each other, and produces the expanded state of the tissue, but that this galvanism is discharged into the nerves of supply at the moment of contraction, causing all the cellules to approximate, by the removal of the cause of repulsion. Something of this kind may occur, but the cause of the discharge is not intelligible. Moreover, chemical actions occur in the brain, and are calculated to produce analogous electrical effects. From this we are led to infer that a galvanic (nervous) current may arise from the brain, and another (muscular) from the muscle; but the laws which determine their action, are unknown. It has been objected to such views that muscle and nerve are not good electrical conductors; but this is an unimportant matter if it be admitted that they differ in conducting power.

The free electricity of the muscle is the product of the chemical changes passing over its parts at all times; but in addition to this, Liebig has found a second source, which, as it throws light on the nutrition of the muscle, we introduce in this place. He has found that the muscular texture is bathed by an acid fluid containing the tribasic phosphate of soda with acid reaction, and lactic acid, whereas, it is well known that the blood and serum, as well as the surfaces of the mucous membranes, the chyle and lymph, possess an alkaline reaction from the presence of the tribasic phosphate with three atoms of base. Now, under these circumstances, a movement will take place in these fluids through the tissues that lie between them, and a galvanic current be generated.

Valli, fifty years before, had proposed a view much more in accordance with facts, than either of the foregoing; he conceived that the galvanism was set free on the surface of the capillaries which supply the nerves, and that it is constantly conveyed to the muscular fibres, which continue charged, until a counter influence from the brain neutralizes their excitement.

We close these observations with the remark, that the similarity in action of the nervous and galvanic forces is such as to induce us to hope for a more complete investigation of the subject, and even to anticipate that hereafter they may be found identical; but manifested dissimilarly in consequence of the organized structure of the body; in the same way that electricity and magnetism, although one agent, have few properties exactly similar, and are apparently opposed in many. One truth is now certain, that galvanism is generated in the body wherever chemical action occurs, as in the changes of nutrition, respiration, and secretion.



## AFFINITY.

AFFINITY was originally employed to designate a particular force which united the molecules of matter together. There were supposed to be three varieties of this force: that which bound together the similar atoms of bodies, which was called *simple affinity* or cohesion—that which determined union between dissimilar molecules, termed *heterogeneous affinity*, or capillary attraction; and lastly, *chemical affinity*, which served not only to unite dissimilar atoms, but also modified their properties, so that they were no longer to be recognized by physical tests. These varieties of force may be readily illustrated. If we press together two pieces of clean lead, or of plate glass, they will adhere, and with considerable force; this is an instance of the operation of the cohesive force. If a perfectly clean piece of plate glass be let down to the surface of pure mercury, they attract one another with considerable force in consequence of the heterogeneous affinity, or capillary attraction, existing between these bodies. In neither of the foregoing instances are the substances altered in figure or sensible properties; but if we now bring nitric acid in contact with the quicksilver, union occurs, attended with the evolution of red fumes, and both the acid and metal lose their properties, the mixture becoming a crystalline solid—this is a case of chemical affinity.

Formerly, there was supposed to be a radical difference between these forms of affinity, but they are now found to be modifications of the same force. Nor is this a new force, *sui generis*, but an instance of electrical action. This may be readily proved: If we cause two plates of glass to adhere by bringing them in close contact, and then separate them, and carry each to the gold leaf electrometer, one will be found negative, and the other positive. This effect will appear in the case of all solids which are insulated; in fluids, the union is too close to enable us to test the electrical state of the parts, but it will be remembered that Pouillet has shown that the disintegration of their molecules is attended with electrical disturbance. In cases of capillary attraction, the electrical force is also active; if the glass and mercury be insulated, it will be found that on separation both develop electricity. In this case, the attraction is completely under the influence of

electricity, for if we place a little water on the surface of mercury, no affinity is apparent; the water collects in drops and insulates itself from the mercury, but the instant we bring the negative pole of a galvanic battery in contact with the metal, and let the positive touch the water, union occurs, the water spreading over the quicksilver, and wetting it completely. In chemical affinity, the electrical force controls the action, as we have shown in page 99. The electro-chemical theory is a sufficient evidence of this position.

There are circumstances in which these agree, as well as points of difference. In every case of affinity, electrical disturbance arises, but it is most violent in the process of chemical union. The force acts only at insensible distances. Newton came to the conclusion that cohesion did not act at a distance exceeding the millionth of an inch, and it is well known that chemical action rarely occurs, unless one of the bodies be fluid or gaseous. Cohesion, capillary attraction, and chemical affinity, are all controlled by electricity. If we electrify two pieces of glass similarly, they repel each other; if dissimilarly, cohesion takes place. Water and saline fluids can be made to mingle with quicksilver, when their electrical states are dissimilar. Chemical union of the most intense nature can be overcome by the galvanic current.

The question whether capillary attraction, or chemical union, shall take place in any case, depends upon the relation between the force which binds the atoms of either body together, and the degree of disturbance. Capillary attraction is, by no means, a universal result of the action of matter; it takes place only between certain bodies, and differs in intensity. Chemical affinity is equally a special result, occurring only between bodies, the electrical relations of which are widely dissimilar; and also differing to a considerable extent in intensity. Clairaut has determined the ratio of the cohesive force to the capillary affinity which produces the rise of fluids in glass tubes, or, what amounts to the same thing, the wetting of a surface by a fluid for which it has an affinity; and Professor Draper has added to this estimate the condition under which chemical union results. These are expressed in the four following laws:

1st. The force which binds together the atoms of a homogeneous body, is electricity, and is called the cohesive force; it is very dissimilar in intensity, in different forms and kinds of matter.

2d. If the electrical attraction of a fluid for a solid be less than half the cohesive force, capillary affinity does not occur, the fluid does not wet the solid, and will be depressed in a minute tube made of the solid.

3d. If the electrical attraction of a fluid for a solid exceeds half,

but is less than the whole cohesive force, it will wet the solid, and rise through its interstices, or in a capillary tube made of it.

4th. If the electrical attraction of a solid or fluid for another fluid exceeds the whole cohesive force, chemical union will occur.

Cases of solution, of the penetration of gases and vapors into one another, of the ascent of fluids into solids, and the passage of mercury through metals, are instances of capillary affinity. In the relation of mercury to solids, we are presented with instances in which the capillary affinity gradually passes into chemical union. If two globules of mercury be brought near to one another, union occurs; this is an instance of cohesion. If iron be brought in contact with this metal, it is in no way affected; the surface is not wetted by the quicksilver, nor does any part of it rise into the interstices of the iron; the cohesive force is greater than the electrical attractions of these substances. But a clean piece of copper or silver brought to the mercury, is instantly affected; they are wetted, and if exposed sufficiently long, become permeated in all directions; the cohesion of their atoms is overcome, and a compound body is produced. But if we examine the action on the silver more particularly, it will be found that a peculiar substance differing from both of the components, is formed; the amalgam assumes the crystalline figure, and becomes no longer a solution of silver in mercury, but a definite chemical body, composed of a fixed number of atoms, and having a certain figure. In this case, the chemical body is produced without any remarkable disturbance of the electrical force (or ether), and seems to be little more than a case of solution, but in most instances a considerable disturbance of heat, light or electricity occurs during chemical union, and characterizes it.

We propose, in this place, to consider chemical affinity, leaving the applications of capillary attraction to the circulation of fluids in animals, to the section on animal chemistry. The subject divides itself into the following sections:

- § 1. *The phenomena of chemical affinity.*
- § 2. *The chemical relations of matter.*
- § 3. *The effects of the chemical force.*

#### § 1. THE PHENOMENA OF CHEMICAL AFFINITY.

It has been remarked that the intense electrical affinity which produces chemical union, is usually attended with phenomena that are not perceptible in cases of cohesion and capillary attraction. In chemical union, we commonly observe the evolution of light, heat, electricity, and change of color, density, form, or other sensible properties, and these appearances decide us in referring

the cause to chemical combination. Bodies which are characterized by intense causticity, as potash and sulphuric acid, become neutral, possessing little action. Intensely colored substances lose their appearance, fluids become solids, gases are converted into crystalline substances, and every variety of change occurs in chemical union.

It is not to be expected that where the active properties, colors, and densities are so altered, the changes should take place without disturbance to the ether contained in the combining substances. This is thrown, in many cases, into intense action; where rapid condensation occurs, great heat is evolved, sometimes gaseous bodies are evolved from solids with explosive violence, or the addition of a fluid throws a solid into intense ignition. Indeed, wherever chemical affinity is considerable, the ether is remarkably affected, and light, heat, electricity, change of color, and explosions, often take place. In these cases, the phenomena indicate chemical action.

By experience, we have discovered that certain bodies, as oxygen, chlorine, iodine, sulphur, are intensely active, combining with most solids; and reviewing this knowledge, we find that those which are high on the electro-negative scale have the greatest affinity for those high on the electro-positive scale (page 102). Their electrical relations being intense and dissimilar, union occurs between them with great force. Nor does chemical union occur between simple substances only, but between such as are highly complex.

*Circumstances which assist Chemical Union.*—The principal of these are: the fluid form, the nascent state, heat, certain electrical states, and light.

The *fluid state* is one of the most essential conditions to the display of chemical action; indeed, formerly it was supposed essential, but we are now acquainted with many instances in which it is not necessary. In the fluid, the cohesive force is considerably less than in the solid, and there is a facility of access among the atoms which allows of their juxtaposition. The interspaces of fluids are also greater than in most solids, and hence the diffusion of matter is more ready. So considerable is the influence of fluidity, that it is often enough to dry up a mixture to stop chemical union, and this is especially true in organic changes, as in fermentation.

*The Nascent State.*—It is found that when a gaseous substance is first made free from its combinations, it is much more active than when aerial. Oxygen, hydrogen and nitrogen are gaseous bodies, and when in their ordinary state, are not remarkable for great activity; indeed, hydrogen and nitrogen are almost inactive, but when first produced from their compounds, and



before they have passed into the state of gases, they are the most energetic substances in nature. It is to be supposed that they are fluids in the nascent state, and being much condensed, act with violence, for if we condense them by spongy platinum, artificially, they become energetic. These are not the only instances where a substance displays a great difference in chemical activity. Chlorine, phosphorus, sulphur, carbon, iron, and perhaps nearly every element, has an active and inactive form. Nor are these merely attributable to the state of condensation, for iron, whether active or inactive, has the same appearance. From these facts, it appears that the ability to display chemical affinity is not a property of the atom so much as of the forces by which it is moved, for if inactive chlorine be exposed to the light, it becomes active; again, if active phosphorus be exposed to the same agent, it becomes inactive. Iron thrown into the electrical state, is inactive to agents with which it readily combines under ordinary circumstances. These states of matter are termed *allotropic*, and the fact of their existence *allotropism*.

*Allotropism* is not simply the fact that many, if not all, elements exhibit an active and inactive state; for some, as carbon, have three allotropic forms, as the diamond, plumbago, and lamp-black. Hence a necessity has arisen for a descriptive nomenclature, especially as there is little doubt that the particular state of an element modifies all its compounds. We find in organic chemistry numerous bodies with the same atoms in similar proportions, but of very different properties, which are called isomeric. Such are oil of turpentine and lemons; carburetted hydrogen, a fetid gas, and otto of roses. In such cases of isomerism, the difference of properties can only be attributed to the presence of the elements in different allotropic states, or to a difference in the arrangement of the atoms. A new nomenclature, with appropriate symbols, has, therefore, been recommended. The active phase has been designated the *alpha* ( $\alpha$ ) state, and, other phases, *beta* ( $\beta$ ), *gamma* ( $\gamma$ ), &c., and the symbols for carbon are written as follows:



In this system, the older term, *nascent*, is rendered *alpha*, or active; and we say that the alpha or active state of elements is favorable to chemical union.

*Heat* favors chemical combination principally by converting solids into fluids. The alloys furnish excellent illustrations of this fact, for the metals have no action whilst solid, but when fused, the particles run together and union results; this is not, however, always of the chemical kind, but often results from capillary attraction. Certain acids, as the silicic (sand), phosphoric and boracic, act feebly, except at high temperatures, when they



become very energetic. In such cases, it is apparent that heat assists chemical action by diminishing the cohesive form. But there are instances where its action is entirely different. For, if we apply heat to some gaseous mixtures (as oxygen and hydrogen), they unite, and often with explosive violence; in such cases, there is little if any influence exercised on the cohesion of the bodies, and the operation can only be accounted for by reference to the molecular disturbance produced in the mixture, and which is propagated with great rapidity. For, as heat is known to disturb the electrical state of many substances, it cannot be doubted that it may act, in this manner, upon a mixture of gases.

The *electrical state* of the matter exerts a complete control over chemical union. This is apparent in the galvanic battery, where, by establishing an electrical state more powerful than that existing between the atoms of a compound, they are dis-severed. It is also apparent in the union produced between gaseous mixtures by the electric spark, which, by disturbing the electrical equilibrium of the mixture, often induces union with explosive violence.

*Light* exerts considerable action, both of union and decomposition, among the molecules of matter. In the vegetable, this is most apparent; here it effects the decomposition of carbonic acid gas, and the union of carbon with water, actions which are remarkably different from those of common chemical affinity. A striking instance of its action is in the conversion of inactive, or  $\beta$  chlorine into  $\alpha$  chlorine, by exposure to the sun's rays for a few seconds.

*Causes which retard Chemical Action.*—The principal causes which impede or arrest chemical action are cohesion, elasticity, and the state of combination.

*Cohesion* acts continually to impede chemical union, where it is considerable, by hindering the apposition of the molecules, between which only the force acts. The hammering, or condensing a metal by pressure, by which we increase the cohesive force between the atoms, renders the substance less destructible than when porous. Heat, on the other hand, by overcoming the cohesion, nearly always assists chemical union, and frequently originates it between bodies which exercise little affinity towards each other.

There is another and very important action of cohesion in modifying chemical union. It has been said that, as a general rule, the bodies highest on the electro-negative list have the greatest affinity for those highest on the electro-positive class, but this principle is perverted in many cases by the influence of cohesion. For, the two bodies which form a solid compound will unite, although they may be low in the list, in preference to those which

are high, but form a fluid by their union. Hence, our measure of affinity is influenced by cohesion as well as the act of chemical union.

*Elasticity.*—A gas is an elastic body, and possesses little chemical activity as compared to a fluid. However great the affinities between substances may be, if one or both are gaseous, they will seldom unite, except under the influence of some disturbing force, as heat, light, or electricity. Again, in decompositions, the substances which are elastic will be produced in preference to those which are fluid. So that elasticity, like cohesion, acts by disturbing the affinities of substances as well as by impeding chemical union.

*Coldness*, by assisting cohesion, diminishes chemical action. This is particularly the case in organic compounds, and in plants and animals. In them the union occurs between numerous atoms, and the product often depends upon the degree of temperature. Fermentations will not take place at temperatures below  $40^{\circ}$  F., and specific kinds of fermentation arise as we increase the heat, although the bodies present remain the same.

*State of Combination.*—The chemical force is called an *elective force*, because one body prefers certain others out of a number, and does not enter promiscuously into union with them all. But whilst we know the ordinary appetite of one substance for another, it is not right to conceive that it will elect it under all circumstances. Thus oxygen has a great affinity for hydrogen, and their union forms water; but whether this affinity shall be satisfied, depends not only on the form of the bodies, but their state of combination. If the oxygen be already united with a metal, the hydrogen will scarcely remove it, although abstractly its affinity may be greater; on the other hand, if we present both bodies in the state of combination, they may meet and form water. Let the hydrogen be combined with chlorine, this constitutes the chloride of hydrogen; let the oxygen be in union with iron, this forms oxide of iron. Bring these together, and *decomposition* occurs; the affinity of the oxygen and hydrogen, though they are combined, determines the destruction of the chloride of hydrogen and oxide of iron; being now separated from their combinations, they unite and form water, the two other substances also combining to form chloride of iron. Thus the state of combination influences the play of affinity.

The second case presents us with an illustration of *double decomposition*, and is to be distinguished from *single decomposition* where the affinity is not controlled, as in the following case of chloride of copper and iron. The latter metal has a great affinity for chlorine, and finds it already united with copper in the chloride of copper; this does not destroy its affinity if the salt be in so-

lution. The iron displaces the copper, which falls in the state of metal, and as this decomposition proceeds, it is ready to unite with every atom of chlorine to form chloride of iron. This is an instance of *simple elective affinity*, and *simple decomposition*.

In instances of *double decomposition*, there must be a more powerful chemical affinity between one pair of elements than between the other, or there must be some other disturbing action, as of cohesion or elasticity. Those bodies, which have the greatest action, are said to exhibit *divellent* affinities, and those which are less active, *quiescent* affinities; and decomposition will only arise where the divellent affinity much exceeds the quiescent.

Hence the state of combination impedes both simple and compound affinities, and is always to be considered in determining the question whether two bodies which are known to have a powerful action on one another under one state of things, shall unite under another phase. Oxygen has the most intense affinity for potassium, but it cannot, whilst in the gaseous state, decompose the chloride of that metal, nor can it affect this change if combined with hydrogen as water.

TABLES OF AFFINITY.—The simple law, already expressed, that bodies most intensely negative, unite with those most positive, serves us when the substances are simple and not compound, and in those cases where the disturbing influence of cohesion, &c. does not operate, but in no other cases. Under this restriction, we may prepare tables, exhibiting the preference of oxygen, chlorine, &c., which are curious, but of little practical importance.

In compounds, containing an acid and base, and called *salts*, we know one side to be electro-positive, and the other electro-negative; but cannot determine, by any general law, what the action of another acid or base may be on the salt. In a simple case, we are aware that soda has an affinity for sulphuric acid, greater than for the nitric, muriatic, acetic, carbonic acids, &c., but this may be modified by very trivial circumstances. A table may be drawn up representing the order of this decomposition for soda, and for sulphuric acid to show their form; but tables of affinity, as designed by Geoffroy, are of no utility.

*Soda.*  
Sulphuric acid,  
Nitric acid,  
Muriatic acid,  
Acetic acid,  
Carbonic acid.

*Sulphuric Acid.*  
Barytes,  
Strontia,  
Potash,  
Soda,  
Lime,  
Magnesia,  
Oxide of silver.

The soda or sulphuric acid being alone and without disturbance, the order of decomposition given above, will be found correct, but in a compound mixture, it cannot be depended upon. The soda table indicates that the carbonate will be decomposed by the acetic acid, the carbonic acid being driven off—that the acetate in its turn will be decomposed by the muriatic acid, the acetic acid which is volatile escaping: now the muriate may be disturbed by the nitric acid, and this by the sulphuric acid. But if we heat the nitrate of soda in the air, it will lose its acid, and become carbonate of soda. Hence the application of heat deranges the chain of affinities.

It may be remarked, as a general rule in analysis, that if we mix together a number of active bodies, the order of affinity will not be followed in their combinations, but there will be produced, by preference, compounds which are solid or gaseous.

## § 2. THE CHEMICAL RELATIONS OF MATTER.

There is a striking difference between the union of bodies by the chemical force and under the influence of capillary attraction. If a grain of disulphate of quinine be mixed with a pint of water, every part will be rendered bitter; the medicine will be diffused equally throughout the whole. This will be found true, whatever the quantity of soluble substance, there being but one limit to solubility, and that is the quantity which can be suspended at a given temperature. But in the case of chemical union, if we add one grain of sulphuric acid to an ounce of potash, the acid will unite with about a grain of this body, leaving the remainder untouched. It will not be found throughout the mass as free sulphuric acid, but as a new substance, sulphate of potash, with properties widely different from the free acid or base. Before we can affect the whole of the potash, a weighed amount of acid must be employed, and we find that their complete union never occurs except in a determinate quantity. If any other acid be used, the quantity will differ before we render the potash neutral. The patient study of the amounts necessary to neutralize, saturate or combine with given bodies, has put us in possession of the *equivalent weights*, or *combining proportions* of substances. These numbers also represent the atomic weights, according to the hypothesis that bodies consist of definite atoms.

We might prepare a table of the combining weights of bodies, in grains or pounds, for practical purposes, but for the convenience of theory, it is preferable to adopt a standard. Some prefer hydrogen, which is the lightest body in nature for unity; others,



for the purpose of facilitating analytical calculations, select oxygen, the most active body, as 100. The former is termed the hydrogen scale, the latter the oxygen scale.

The proportions in which the atoms of bodies combine, are fixed and unalterable; they are true for those which, like the metals and certain gases, have never been decomposed, and are called *elementary*, and those which are well known to consist of two or more *elements* in combination. Indeed, if we know the equivalent or combining proportional of the elements of which any compound, as an acid or base, is formed, we also know that of the compound—for it is the sum of the equivalents of the number of atoms present. Thus, sulphuric acid is known to consist of one equivalent or atom of sulphur, the proportional of which is 16.12, and three atoms of oxygen; the number for oxygen being 8, three times will be 24; hence the proportional for the acid is 40.12, which represents its combining number in every case. Again, where union occurs between two salts, or in organic bodies which contain many atoms, it follows the foregoing simple law. Therefore, all that is necessary is a table of the equivalents of the elementary bodies, the rest being deduced by calculation. For convenience, it is customary to employ the initial letters of the English or Latin names of the elementary bodies, instead of writing them in full. These are called the *symbols*, and when a compound is designated, the symbolical letters are connected by a + sign to indicate their union.

TABLE OF THE ELEMENTARY BODIES OF CHEMISTRY WITH THEIR SYMBOLS AND COMBINING PROPORTIONS ACCORDING TO THE HYDROGEN AND OXYGEN SCALES.

Names of the elements. <i>Non-metallic and electro-negative bodies.</i>	Symbol.	Equivalent weights.	
		Hydrogen scale.	Oxygen scale.
<i>Oxygen</i> . . .	O. . .	8.01 . .	100.0
<i>Fluorine</i> . . .	F. . .	18.74 . .	233.8
<i>Chlorine</i> . . .	Cl. . .	35.47 . .	442.6
<i>Bromine</i> . . .	Br. . .	78.39 . .	978.3
<i>Iodine</i> . . .	I. . .	126.6 . .	1579.5
<i>Sulphur</i> . . .	S. . .	16.12 . .	201.17
<i>Selenium</i> . . .	Se. . .	39.63 . .	494.6
<i>Tellurium</i> . . .	Te. . .	64.25 . .	801.76
<i>Nitrogen</i> . . .	N. . .	14.0 . .	175.0
<i>Phosphorus</i> ? . .	P. . .	31.44 . .	392.3
<i>Silicon</i> . . .	Si. . .	22.22 . .	277.3
<i>Boron</i> . . .	B. . .	10.91 . .	136.2
<i>Carbon</i> . . .	C. . .	6.08 . .	76.0
<i>Hydrogen</i> . . .	H. . .	1.00 . .	12.5



Names of the elements. <i>Metallic and electro-positive elements.</i>	Symbol.	Equivalent weights.	
		Hydrogen scale.	Oxygen scale.
Potassium . . .	K.	39.26	489.9
Sodium . . .	Na.	23.31	290.9
Lithium . . .	L.	6.44	80.3
Barium . . .	Ba.	68.66	856.9
Strontium . . .	Sr.	43.85	547.3
Calcium . . .	Ca.	20.52	256.0
Magnesium . . .	Mg.	12.69	158.3
Aluminium . . .	Al.	13.7	171.2
Glucinum . . .	G.	26.54	331.3
Yttrium . . .	Y.	32.25	402.5
Zirconium . . .	Z.	33.67	420.2
Thorium . . .	Th.	59.83	744.9
Cerium . . .	Ce.	46.05	574.7
Lanthanum . . .	La.	—	—
Didymium . . .	D.	—	—
Erbium . . .	E.	—	—
Terbium . . .	Tr.	—	—
Manganese . . .	Mn.	27.72	345.9
Iron . . .	Fe.	27.18	339.2
Cobalt . . .	Co.	29.57	369.0
Nickel . . .	Ni.	29.62	369.7
Zinc . . .	Zn.	32.31	403.2
Cadmium . . .	Cd.	55.83	696.8
Lead . . .	Pb.	103.73	1294.5
Tin . . .	Sn.	58.92	735.29
Bismuth . . .	Bi.	71.10	886.9
Copper . . .	Cu.	31.71	395.7
Uranium . . .	U.	217.26	2711.4
Mercury ? . . .	Hg.	101.43	1264.8
Silver . . .	Ag.	108.3	1351.6
Palladium . . .	Pd.	53.36	665.9
Rhodium . . .	R.	52.20	651.4
Iridium . . .	Ir.	98.84	1233.5
Platinum . . .	Pt.	98.84	1233.5
Gold . . .	Au.	199.21	2486.0
Osmium . . .	Os.	99.72	1244.5
Titanium . . .	Ti.	24.33	303.66
Tantalum . . .	Ta.	184.90	2307.4
Tungsten . . .	W.	94.80	1183.0
Molybdenum . . .	Mo.	47.96	598.5
Vanadium . . .	V.	68.66	856.9
Chromium . . .	Cr.	28.19	351.8
Antimony ? . . .	Sb.	129.2	1612.9
Arsenic ? . . .	As.	75.34	940.1

The substances in this table marked with ? have their combining proportionals in some doubt. Several bodies placed in the list of metals are also electro-negative in their characters, especially arsenic and antimony, whilst hydrogen and nitrogen possess

the properties of metals. The substances printed in Italics are of particular interest to the physician.

From the above enumeration, it will appear that there are fifty-eight elements known to chemists, but some three or four of these are in doubt; the greater number are also mineralogical curiosities, having little interest and of no known utility. Forty-four are metallic and more or less electro-positive, whilst fourteen, or, according to some authors, ten, are non-metallic and powerfully electro-negative, uniting with most of the former class.

Three classes of bodies result from this union, respectively called—*acids*, *bases* and *salts*. Acids are usually of a sour taste, often caustic; they change vegetable blues to red, are electro-negative, and combine with bases to form the common salts. Bases are not distinguished by the foregoing characters; they are also electro-positive, and combine with acids. Salts are the products of the union of acids with bases, usually, but there is a class of substances, of which common table salt is an instance, which are very similar to the common salts, but contain neither an acid nor base; such are termed *haloid salts*. They are compounds of the haloid electro-negative substances, chlorine, bromine, iodine, fluorine, cyanogen, &c., with metals. We do not, however, confine the term acid to bodies which are sour, and redden blue infusions, for many have neither of these qualities, but their essential feature is the ability to combine with a base.

THE ATOMIC THEORY.—The student will now be prepared to understand the beautiful speculation of Dr. Dalton, called the atomic theory. According to this view of matter, it consists of indivisible minute atoms, among which union takes place. These are supposed to be spheroidal and unchangeable, with a fixed weight, and probably of uniform size. Being unalterable and of an invariable weight, called the atomic weight, union can only occur atom to atom and in fixed weight. The equivalents given in the table are supposed to represent the relative densities of the atoms of different elements. Hence it will appear a necessary consequence of this view, that compounds should have an equivalent which is the sum of their atomic weights.

Another consequence of this theory is, that bodies combine atom to atom, or one atom to two, three, four, or more of another substance, or that the weight of any component must be a simple multiple of its equivalent or atomic number. The atomic weight of oxygen is usually taken as 8, and this body is present in different compounds in the weight of 16, 24, 32, 40, 48, but never in other proportions. These, it will appear, are simple multiples of 8, and represent 2, 3, 4, 5, 6 atoms. A second series, in which two atoms of a body combine with three, five or seven of another, is also possible, and such compounds are known in chemistry.

The laws of combination, therefore, flow from the atomic theory, and are remarkably simple for inorganic or mineral matter, in which there are seldom more than five to seven atoms of any element present. There are but two series in which bodies unite.

1st. 1 atom of A to 1, 2, 3, 4, 5, 6, 7 atoms of B.

2d. 2 atoms of A to 1, 2, 3, 4, 5, 6, 7 atoms of B.

The fixedness of the weight, and the equivalent of the compound body, result from the hypothesis that the indivisible atoms have certain weights.

In organic compounds, these simple numbers do not obtain, for some bodies have several hundred atoms, but with the exception of complexity, there is nothing in their history opposed to the atomic theory.

*Symbols for Compound Bodies.*—The abbreviations employed in treating of the elements, are particularly useful in writing the composition of compound and organic substances. For this purpose several styles are employed.

When the substance consists of two elements, or is of a binary form, the electro-positive body (or metal *M*) is placed on the left hand, and the electro-negative (or radical *R*) is placed to the right hand. Thus :

*M. R.*

If the metal be copper, and the radical oxygen, it is written  
CuO.

In these cases, one atom is always indicated by the capital standing alone ; if there be more, the number must be placed on the right and below, thus :

Cu<sub>2</sub>O.

In any compound, all the elements present are introduced, with figures to represent the number of each ; the elements being placed from the right to the left hand, in the order of their electro-positive power. The following is the *formula* for starch :

C<sub>12</sub>H<sub>10</sub>O<sub>10</sub>.

The parenthesis is occasionally used to distinguish the state in which some of the elements are united. In the annexed *formula*, the substance in the parenthesis has the relation of a compound base to that placed exteriorly :

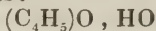
(C<sub>4</sub>H<sub>5</sub>)O.

It represents the structure of ether, which, according to this plan, consists of two distinct parts, a compound base C<sub>4</sub>H<sub>5</sub> = ethyle, united with oxygen, which is neither the only body with which it forms compounds, nor is it immovable from its position. A modification of this is employed when the compound base exists in several proportions :

2(C<sub>4</sub>H<sub>5</sub>) and 3(C<sub>4</sub>H<sub>5</sub>) ;

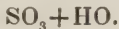
the numbers 2 and 3 here do not affect any term of the formula, except that in the parenthesis.

A comma is employed to designate the combination of two compound bodies. Thus:



indicates that the HO (hydrogen and oxygen, or water), is united with the compound base more feebly than the O or oxygen. This formula represents alcohol, or the hydrated oxide of ethyle.

If the affinity between the compounds be feeble, we use + (plus) between the terms, as

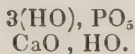


A vinculum or band is employed to indicate that the symbol does not belong to the table of elements, but to an organic compound. Thus

 $\overline{T}$ 
 $\overline{Pr}$ 
 $\overline{C}$ 

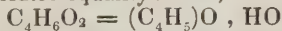
represent three well known organic bodies. The  $\overline{T}$  being tartaric acid, the  $\overline{Pr}$  proteine, and the  $\overline{C}$  citric acid.

Sometimes we find the same term placed before and after a formula. Thus,



In the first, the HO (water) acts the part of a base to the  $PO_5$ , which is phosphoric acid; in the second, the HO acts the part of an acid to the CaO or lime.

The sign = indicates equality: thus,



indicates that the first is identical with the second, which is the theoretical or rational formula.

#### NOMENCLATURE.

Nothing has served to advance the science of chemistry more than an accurate nomenclature. The names of compounds are formed by rule, and not at the option of the discoverer, and make known to every one, the bodies present, and the number of atoms of each ingredient. The laws of nomenclature are exceedingly simple, and are as follows:

1. The names of elementary bodies are those by which the substances are best known, as Copper, Iron, Lead; but when a new body is discovered belonging to this class, it is to be called by a name compounded of two Greek or Latin words, representing its most remarkable properties, or by the name of the mineral from which it is procured. It is wrong to call the new element by the name of a man or country, for, in this way, no informa-

tion is imparted, of chemical interest. The most important bodies of chemistry are well named; thus *oxygen*, formed from Greek words signifying *I generate an acid*, indicates that, according to the views of the author, it is the principle of acidification. *Hydrogen* comes from *I form water*, because it exists in that fluid.

2d. In a substance containing two elements, (*binary*,) the names of both are introduced; the electro-negative body being written first, and terminating in *ide*, if it be a *base*; or, if the combination be of two metallic bodies, the most active is put first, and ends in *uret*.

Thus, a basic compound of oxygen with iron, is termed an *oxide of iron*.

Oxygen	becomes	Oxide
Chlorine	"	Chloride
Iodine	"	Iodide
Bromine	"	Bromide
Sulphur	"	Sulphide
Cyanogen	"	Cyanide.

Sulphur is frequently written *sulphuret*; so is selenium, *selenuret*; phosphorus, *phosphuret*; but the terminations should be in *ide*, as suggested by Dr. Hare.

Hydrogen, Carbon, Arsenic, and Antimony, are the principal metallic bodies which combine with other metals, and are rendered—

Carbon	—	Carburet
Arsenic	—	Arseniuret
Antimony	—	Antimonuret
Hydrogen	—	Hyduret
Nitrogen	—	Nituret.

Compounds of mercury with metals are termed *amalgams*; combinations of the common metals *alloys*.

3d. If the amount of the electro-negative body be more than one atom, and the substance basic, it is designated by the Greek words, *protos*, first; *deuteros*, second; *tritros*, third; as

Protoxide of iron, or first oxide of iron,  $\text{FeO}$ .

Deutoxide of manganese, or second oxide of manganese,  $\text{MnO}_2$ .

Tritoxide of iron, or third oxide of iron,  $\text{FeO}_3$ .

The contraction of the numerals follows the ordinary laws of composition. We write

Deutiodide—Tritochloride—Protosulphuret.

But, in many cases, it is not certain that the compound contains two, three, or more atoms of the electro-negative; and the comparative terms, *per* for the highest amount, and *sub* for the



lowest, are used. We have, therefore, the per-oxide, per-chloride, and sub-oxide, sub-chloride.

*Sesqui* (one and a half) is likewise employed to signify that the atoms of the electro-negative bear the ratio of  $1\frac{1}{2}$  to 1 of the metal, or of 3 to 2. We have the *sesqui-oxide of iron*,  $\text{Fe}_2\text{O}_3$ ; *sesqui-sulphuret of arsenic*,  $\text{As}_2\text{S}_3$ .

It is to be observed that this law is often violated, and the Latin terms *bis*, twice; *ter*, three times, &c., employed in the place of the Greek words.

Thus Binoxide is often used for Deutoxide	
Bichloride	" Deutochloride
Teroxide	" Tritoxide
Terchloride	" Tritochloride.

4th. When the number of atoms of the metal are in excess over the electro-negative, it is indicated by employing the terms *dis*, twice; *tris*, three times; and thus, the *Dioxide of Copper* is a body in which there are two atoms of copper united with one of oxygen, or  $\text{Cu}_2\text{O}$ .

5th. When the binary compound has acid properties, the name of the electro-positive element is terminated in *ous* or *ic*. The first is used where there are two acids—the other containing more of the electro-negative; if there be but one acid, it is terminated in *ic*. Thus sulphur forms two strong acids with oxygen—the one containing least oxygen is called *Sulphurous acid*; the second, *Sulphuric acid*. We have also *Nitrous* and *Nitric acids*; *Phosphorous* and *Phosphoric acids*.

Sometimes more than two acids are formed by the union of one electro-positive with an electro-negative body, then the comparative terms *hypo* below, and *hyper* above, are employed. We have a *hypo-sulphurous* acid, which, as the name indicates, contains less oxygen than the sulphurous acid. We have also the *hypermanganic* acid, and *hyperchloric* acid, which severally contain more of the electro-negative body (oxygen) than the manganic and chloric acids.

Five sets of acids may, therefore, exist:

A hypo acid in *ous*, as the hyposulphurous acid,  $\text{S}_2\text{O}_2$ .

A hypo acid in *ic*, as the hyposulphuric acid,  $\text{S}_2\text{O}_5$ .

An acid in *ous*, as the nitrous acid,  $\text{NO}_2$ .

An acid in *ic*, as the phosphoric acid,  $\text{PO}_5$ .

An acid in *hyper*, as the hyperchloric acid,  $\text{ClO}_7$ .

6th. The compound formed by an acid and base is called a *salt*. But as there are five acids, there will be five series of salts, and these are distinguished by terminating the acids of *ous* in *ite*, and the acids of *ic* in *ate*. In writing the name of the salt, if

there be one atom of either component, the acid with its appropriate termination is placed first, and the metal second, if it be a protoxide. Thus: *Sulphate of iron* means a compound of *sulphuric* acid with protoxide of iron, for there is no such substance as the sulphate of metallic iron. The acids of salts are, therefore written—

Hyposulphite  
Hyposulphate  
Nitrite  
Phosphate  
Hyperchlorate.

The salts being termed *Hyposulphite of Soda*, *Nitrite of Potash*, *Phosphate of Iron*, *Hyperchlorite of Potash*, &c.

Some authors write *protosulphate*, *protophosphate*, to indicate that it is the protoxide of the metal which is combined with one atom of the acid. Others, nitrate of the protoxide; but this is not necessary.

7th. If there be more than one atom of the acid, the Latin terms *bis*, twice; *tris*, three times, &c., are employed, as *Bisulphate* of potash, *Bicarbonate* of soda, &c.

In these cases, the compound is called a *supersalt*, to distinguish it from the *neutral* salt in which the acid and base are combined equally, and the *subsalt* in which the base preponderates. But it is to be remarked, that many acids, especially those of organic chemistry, are *polybasic*, or have the power of saturating two or more atoms of base. Such are phosphoric, tartaric, citric, and other acids. Those which saturate two atoms, are called *bibasic*, those which can combine with three atoms, as phosphoric acid, *tribasic*.

8th. If the oxide of the base be not a protoxide, but a deutoxide, tritoxide, &c., the terms *deutos*, *tritros*, *sesqui*, &c., are placed before the name of the acid. As

<i>Deutosulphate</i>	—	<i>Tritosulphate</i>
<i>Sesquisulphate</i>	—	<i>Persulphate</i> .

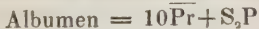
Compounds of this kind are not, however, numerous, the protoxide being the active base in most cases.

*Failure of the Nomenclature.*—The foregoing nomenclature is all that can be wished for most inorganic compounds, which seldom contain more than five elements, or unite in proportions exceeding five to seven atoms. We are enabled, by means of it, to attain the chemical history of the substance by inspection. Take the *nitrate of lead* as an illustration; we discover from the word nitrate that the element nitrogen is the electro-positive constituent of the acid, and that it is the most oxygenized acid from the termination in *ate*, or that the *nitric* acid is present; the other term

also informs us that the base is a protoxide of lead, for otherwise it would be called the *deutoxide* or *deutonitrate*.

But in organic compounds, which contain many hundred atoms, this nomenclature is altogether inapplicable. Fibrine, an important component of plants, and a constituent of blood has the formula  $C_{480}, H_{360}, N_{60}, O_{140} + SP$  or 1042 atoms; it would be impossible to describe this by any name which included the elements and their number of atoms. In such cases, a contraction is used for a part of the formula, wherever it can be shown that the elements are not united by the same force. In the above, the + sign indicates that the P and S (phosphorus and sulphur) are feebly combined with the first part of the formula. By distinct researches, the first part is found to unite with other substances in the number of atoms given above, and also in one-tenth these numbers; or that there is a body consisting of  $C_{48}, H_{36}, N_6, O_{14}$ , and this unites with oxygen, chlorine, &c., or 10 times this, or fifteen or other proportions of it combine with sulphur, &c., hence it is called the *radical* of the compound, and to distinguish it from the elementary radicals, it is called the *compound radical*, and is furnished with a distinct name, *proteine*, and symbol  $\overline{Pr}$ .

The introduction of compound radicals into organic chemistry has done more to advance the science than any other circumstance, by enabling us to trace intimate connections between bodies otherwise widely separated in properties, and in some cases enabling us to produce organic changes of great interest. The compound radicals of most interesting bodies are now known, and they are all furnished with symbols, which greatly facilitates the writing and nomenclature of animal and vegetable chemistry. Thus there is no apparent connection between albumen, cheese and fibrine, except that they are nutritious bodies; if we write out their entire formula, they present great complexity; but having discovered that the compound radical *proteine* is present in all, and by analysis that they also contain sulphur or phosphorus in different proportions, we write their formulas as follows:

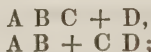


and see at once their points of connection and distinction. We discern that all contain 10 atoms of the organic, or compound radical  $\overline{Pr}$  (*proteine* =  $C_{48}, H_{36}, O_{14}, N_6$ ) with specific quantities of sulphur and phosphorus.

Therefore in organic chemistry, we do not pretend to employ the nomenclature given for minerals; but whenever the opportunity occurs, employ a contraction to express a compound body, and call it the compound radical. But if this unites with one,

two, or three atoms of an electro-negative, as oxygen, chlorine, iodine, cyanogen, &c., we employ the ordinary terms for bases, and call the substance a protoxide, protochloride, deutoxide, deutiodide or tritoxide. Thus we have the deutoxide and tritoxide of proteine. The oxide of ethyle.

The nomenclature also fails in isomeric compounds. Thus we may have two or more distinct bodies produced with the same elements in the same proportions; but the above laws direct that we should in the name unite the designation of each element with the number of atoms of each, and thus no difference will appear in the name. Four atoms may be grouped in different ways, thus:



and this may materially affect the sensible properties. In such cases, the method of symbols is the only means of making the difference appear in writing. This subject has already been alluded to in the remarks on *Allotropism*.

**OTHER THEORIES OF COMBINATION.**—In the foregoing, it has been assumed that bodies unite atom to atom, but it is true in the case of gases and the vapors of some bodies to assume that they combine by *volumes*; or that combination results from the mixture of substances in certain weights which have no relation to their ultimate parts or atoms.

Hence we often find it stated, that the combining volume of a gas is a given quantity, and that it unites in that number or its multiple only. Observation has determined that the combining volume differs for different gases, according to the following table:

TABLE OF THE COMBINING VOLUMES OF GASES AND VAPORS, THAT OF HYDROGEN BEING 100.

Gas or vapor.	Combining volume.
Hydrogen - - - - -	100
Nitrogen - - - - -	100
Chlorine - - - - -	100
Iodine - - - - -	100
Bromine - - - - -	100
Carbon (hypothetical) - - - - -	100
Mercury - - - - -	200
Oxygen - - - - -	50
Phosphorus vapor - - - - -	25
Arsenic " - - - - -	25
Sulphur " - - - - -	16.66

According to this theory, hydrogen, nitrogen, &c., unite only in quantities representing a volume of 100, 200, 300, 400, and, as we know that these substances combine according to their atomic weights or equivalents, we would infer that the weight of these volumes would be the same as the atomic weights;



and such is found to be the case in most instances. This view of combination, therefore, indirectly sustains the atomic theory.

The second theory, that bodies combine in fixed weights, called their equivalents or combining numbers, has already been explained, and it differs in nothing from the laws of combination detailed in the preceding pages, except that these weights are supposed to have no relations to the atoms. In the present day, we speak of the union of one atom of sulphur with two atoms of oxygen, which involves a recognition of the atomic theory; formerly it would have been said that one *prime* or *combining* weight of sulphur united with twice the equivalent of oxygen, which does not indicate an approval of the atomic theory. The numbers are also often written thus: 14 sulphur + 16 oxygen, which does not lead us to infer that oxygen unites in any other number, and therefore is merely an experimental fact distinct from any hypothesis.

In the present day, the writings of chemists are all based on the atomic hypothesis, whether it be admitted or otherwise, for without this, the system of symbols would be useless:  $C_2H_2O_6$  are terms indicating that there are 2, 4, or 6 definite amounts of carbon, hydrogen, and oxygen. If we would write on the view that the compound takes place in given weights only, we should have to express the above differently, as carbon 12 parts + hydrogen 4 parts + oxygen 48 parts, which gives no information of other compounds of these elements.

### § 3. RESULTS OF THE CHEMICAL FORCE.

The chemical force is essentially a molecular force; it acts by setting in motion the atoms or ultimate particles of bodies, and arranging them in a new order. Whether heat, light, &c., be evolved during this process, will be dependent on the resistance and other properties of the matter and ether, and does not flow as a necessary consequence of the operations of this force. Increase of density, the elastic state and other physical changes, are also of a partial nature, and peculiar to certain substances. But a new molecular arrangement is a necessary consequence of chemical action. We do not pretend to know what imparts to substances the sweet, sour, or neutral taste, but may infer with some plausibility that these are consequences of the grouping of the atoms. We know that there exists a tasteless and sapid variety of sugar, a soluble and insoluble form of gum, and in both instances the kind and number of atoms are similar; the difference between them being probably due to dissimilarity of grouping, under the influence of the chemical force. So, again, we know that the mole-



cular arrangements called *crystals*, sometimes have their figures changed by the presence or absence of heat during their aggregation.

The three most remarkable molecular effects of the chemical force, are

*Determinate crystalline figure;*  
*The production of groups and types;*  
*Catalysis.*

#### CRYSTALLIZATION.

Those solids which have regular geometrical figures are called crystals, to distinguish them from mere shapeless, or *amorphous* masses. The crystals may be separate, and their facets and angles apparent, or confused together, or hidden as in ice and several metals. In the latter cases, they may be separated by breaking or *cleaving* the crystalline mass in the direction of its facets. The crystals, when examined more attentively, are found to be symmetrical in all their parts, so that the minutest portion as well as the mass presents a certain figure.

The crystal is characteristic of the elements present, or of certain groups of elements, and the nature of their union. Hence, in mineralogy, the figure of a substance enables us in many cases to determine its components.

To obtain crystals, it is necessary that the solution in which the chemical changes have transpired, be evaporated, or the solvent removed, so that the atoms may obey the force which determines their aggregation. Otherwise they are solicited by the capillary force, and diffuse themselves in the liquid, producing a solution. Fine crystals are procured by slow evaporation; whenever they are hurriedly formed, they are imperfect. Besides evaporation, crystals are formed by long-continued galvanic action, by cooling from fusion or hot solutions, or by the refrigeration of some vapors. The finest crystals in nature are produced by long-continued electrical currents.

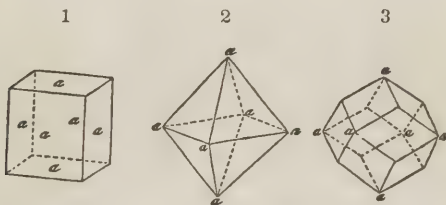
In determining the form of a crystal, we are not so much influenced by the number of faces as by the angles which they form with one another, and the relations of their *axes*. Every crystal has three or more axes, one of which is a straight line, passing from above to the lower side, and called the *principal axis*; and the others, passing from side to side, are called the *secondary axes*. The figure of the crystal depends upon the lengths of these axes and their angle to one another.

There are six systems of crystals recognized in the works on crystallography.

1. The regular system.
2. The square prismatic system.
3. The right prismatic system.
4. The oblique prismatic system.
5. The doubly oblique prismatic system.
6. The rhombohedral system.

1st. *The Regular System*.—In this class there are three equal axes, all of which are at right angles to each other. It contains (Fig. 40) the *cube*, 1; the regular *octahedron*, 2; and the *rhombic dodecahedron*, 3.

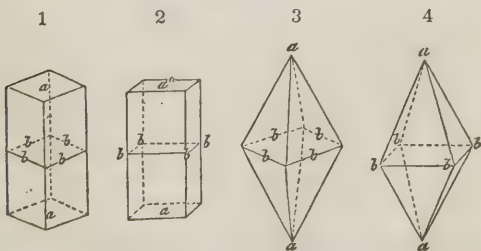
Fig. 40.



The letters  $a-a$ , in the above figures, represent the points between which the three axes pass. These are very common forms of crystal; the diamond, most metals, alum, fluor spar, common salt and the garnet, furnish instances.

2d. *The Square Prismatic System*.—The principal or perpendicular axis  $a-a$ , is in this class longer than the other two  $b-b$ , which are equal; but the whole are at right angles to each other. The most important forms, are: 1, the *right square prism*, with the secondary axes  $b-b$ , passing from face to face; 2, the *right square prism*, with the secondary axes passing between the lateral angles; 3, the *right square based octahedron*, with the axes as in 1; 4, the *right square based octahedron*, with the secondary axes, as in 2.

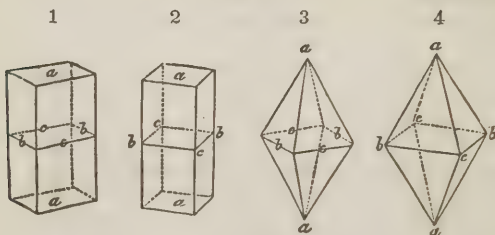
Fig. 41.



The zircon, yellow prussiate of potash and native oxide of tin, furnish examples.

3d. *The Right Prismatic System*.—In this class, there are three axes of unequal lengths  $a—a$ ,  $b—b$ ,  $c—c$ , but placed at right angles to each other. The chief forms are: the *right rectangular prism*, 1, Fig. 42; 2, the *right rhombic prism*; 3, the *right rectangular-based octahedron*; and, 4, the *right rhombic-based octahedron*.

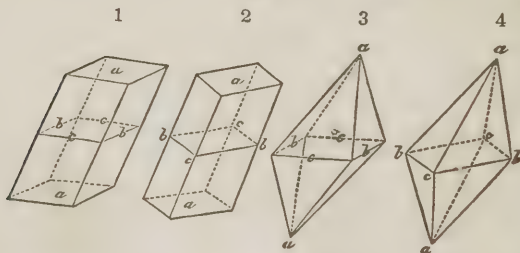
Fig. 42.



Nitrate and sulphate of potash, sulphur crystallized at a low heat, and arsenical sulphuret of iron, furnish illustrations of this system.

4th. *The Oblique Prismatic System*.—In this class, there are three axes, all of which are sometimes unequal. The two lateral or secondary axes,  $b—b$ ,  $c—c$ , are at right angles to one another, whilst the primary axis  $a—a$  is perpendicular to one of them, and oblique to the other. The four figures of Fig. 43 belong to this system: 1 is the *oblique rectangular prism*; 2, the *oblique rhombic prism*; 3, the *oblique rectangular-based octahedron*; 4, the *oblique rhombic-based octahedron*.

Fig. 43.

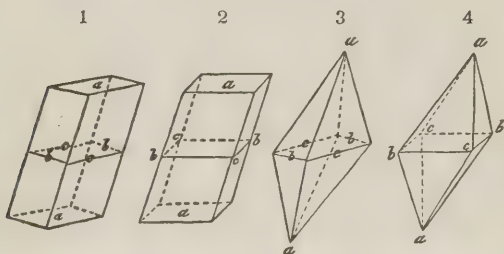


There are numerous illustrations of this system; the carbonate,

sulphate and phosphate of soda, baborate of soda, sulphate of iron, and sulphur crystallized by fusion, offer instances.

5th. *The Doubly Oblique Prismatic System*.—The characteristics of this system are, the obliquity of all the three axes, and their difference in length. The crystals have the appearance of great irregularity in consequence of this want of uniformity. The figure represents four species: 1 is the *doubly oblique prism*, with the secondary axes  $b$ — $b$ ,  $c$ — $c$ , proceeding from the sides; 2, another form of *doubly oblique prism*, with the secondary axes proceeding from the angles; 3 and 4 are corresponding *doubly oblique octahedra*.

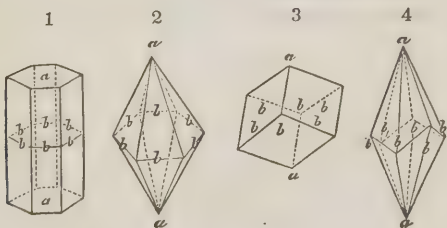
Fig. 44.



To this system belong the crystals of sulphate of copper or blue vitriol, quadroxalate of potash, and nitrate of bismuth.

6th. *The Rhombohedral System*.—The characteristics of this class are striking; there are four axes, the three lateral or secondary of which are equal in the same plane, and form an angle of  $60^\circ$  with each other; the fourth, or principal axis, is unequal and perpendicular to the plane of the other three. To this class belong: 1, the *regular six-sided prism*; 2, the *quartz dodecahedron*, or dodecahedron with regular triangular facets; 3, the *rhombohedron*; 4, the *triangular faced dodecahedron*, with scalene angles.

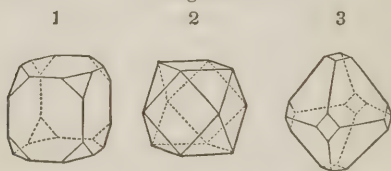
Fig. 45.



This is a very numerous and important system ; quartz, arsenic, antimony, nitrate of soda, ice and calcareous spar, furnish familiar illustrations.

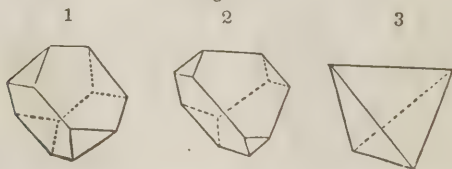
*Causes disturbing the figure of the Crystal.*—In the foregoing illustrations, we have presented the perfect forms belonging to each system. To obtain them in this state of perfection, the deposition of the solid must be very uniform, and it is found that a mild and equable temperature with darkness is conducive to this end. If the density of the solution in which they are forming, or the temperature of its parts, be variable, an excess of deposit will take place on certain facets, and thus the figure may be made to differ considerably from the *primary form*. But, however complex, the *secondary* or derived crystal will belong to the same system, the relations of the axes in direction and length being maintained in the case of every departure from the primary. The figure (46) represents a common case of irregular deposition, by which the cube 1 has its angles bevelled or replaced, which action becoming more considerable, converts it into the dodecahedron with rhomboidal facets 2, and becoming excessive, changes it into the octahedron with truncated angles 3. It will be perceived that all of these belong to the regular system of crystallization, and the cube may be often derived by cleavage from the modified solid.

Fig. 46.



The series of changes may go so far as to develop only half the crystal, so that a half-sided or *hemihedral* crystal is produced, the deposition being on alternate facets, instead of taking place on every side. The tetrahedron is in this way derived from the regular octahedron, as represented in the figure (47), in which 1

Fig. 47.





represents a modified octahedron, four of the sides being much more developed than the other four; 2 indicates a still further inequality of deposition; and 3 shows the resulting tetrahedron, in which the four small sides are altogether obliterated.

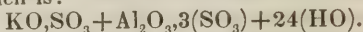
The influence of heat, when considerable, even alters the system to which the crystal belongs. Thus sulphur is found in two forms, as an octahedron with rhombic base when obtained at low temperatures, and as an oblique prism belonging to the fourth class when procured by fusion. Carbonate of lime crystallized at a low temperature has the rhombohedral form, but formed at the boiling point of water, it takes the figure of a right rhombic prism. The diamond and other substances evince the same tendency to crystallize in two incompatible forms. Such bodies are termed *dimorphous*. It is probable that other agents besides heat have considerable influence in altering the crystalline figure, for we know that phosphorus, which is amorphous, becomes beautifully crystallized when exposed to the sun's light.

*Relation between the Crystalline Form and the Constitution and Properties of Bodies.*—ISOMORPHISM.—Professor Mitscherlich was the first to point out the close chemical relation often existing between bodies which have a similar crystalline figure. This is especially true with those belonging to the 2d, 3d, 4th and 5th systems, the first and sixth containing so many objects, that it is difficult to trace any chemical connection amongst them. Hence similarity of figure is not necessarily associated with chemical constitution.

The relationship discovered by studying the geometrical forms of a number of bodies, was found to subsist between many substances which were not crystalline. Thus it appeared that the substitution of bromine or iodine in a compound could be effected by chlorine, which is a gaseous substance, and the resulting body still retain its crystalline form. Hence many elementary bodies are termed isomorphous which have no direct relationship in their figure, but produce compounds which have a crystalline similarity.

The doctrine of isomorphism is not limited to the fact that when two crystals belonging to the 2d, 3d, 4th or 5th systems, are examined and found to agree, we are in a measure assured of a similar constitution, or that if the one contain two or three atoms, the second will likewise contain two or three atoms, but it also establishes a relationship between the elements or compounds present, which can be traced through numerous instances; and lastly, it leads us to infer that one isomorphous body may replace in part or in whole, another. Hence the crystal is no longer an absolute test of the substances present, for it may be compounded of every isomorphous substance without change of

form. The following is a striking instance: common crystalline alum is a double salt, consisting of four atoms of sulphuric acid with one of potash, one of alumina and twenty-four of water, the formula of which is:



In this list of substances, the potash (KO) is isomorphous with soda (NaO), with ammonia (oxide of ammonium AmO), and other bodies; the sulphuric acid (SO<sub>3</sub>) is isomorphous with the chromic acid (CrO<sub>3</sub>), the selenic acid (SeO<sub>3</sub>), and manganic acid (MnO<sub>3</sub>); the alumina (Al<sub>2</sub>O<sub>3</sub>) is also isomorphous with peroxide of iron (Fe<sub>2</sub>O<sub>3</sub>), sesquioxide of manganese (Mn<sub>2</sub>O<sub>3</sub>), and sesquioxide of chrome (Cr<sub>2</sub>O<sub>3</sub>). It will be perceived that the bases and acids enumerated have a similarity of constitution, and experimentally they are known to act as substitutes for one another.

Hence a crystalline body having the figure, and, in most cases, similar properties to alum, may be made up of any or all the above substances. The sulphuric acid may be in part or entirely substituted by the selenic, manganic or chromic acids, or some of each may be present. So the crystal may contain potash, soda, oxide of ammonium, iron, alumina, manganese, &c., for its bases. The following varieties of alum can be made artificially:

Potash alum	=	KO, SO <sub>3</sub> + Al <sub>2</sub> O <sub>3</sub> , 3(SO <sub>3</sub> ) + 24(HO)
Soda alum	=	NaO, SO <sub>3</sub> + Al <sub>2</sub> O <sub>3</sub> , 3(SO <sub>3</sub> ) + 24(HO)
Ammonia alum	=	AmO, SO <sub>3</sub> + Al <sub>2</sub> O <sub>3</sub> , 3(SO <sub>3</sub> ) + 24(HO)
Iron alum	=	$\left. \begin{array}{l} \text{KO} \\ \text{AmO} \end{array} \right\}, \text{SO}_3 + \text{Fe}_2\text{O}_3, 3(\text{SO}_3) + 24\text{HO}$
Chrome alum	=	$\left. \begin{array}{l} \text{KO} \\ \text{AmO} \end{array} \right\}, \text{SO}_3 + \text{Cr}_2\text{O}_3, 3(\text{SO}_3) + 24\text{HO}.$

After this it will appear that there is a close connection between figure and chemical history, and that a crystalline form expresses nothing except that its components belong to a certain group of isomorphous bodies, and are combined according to certain laws. Nor is the number of atoms present always similar in the formula given for the alums; it will be seen that the bodies which substitute the alumina (Al<sub>2</sub>O<sub>3</sub>) and sulphuric acid (SO<sub>3</sub>) have a similar structure, namely, two atoms of metallic element to three of oxygen in the first, and one atom of sulphur or other element with three of the electro-negative; but the oxide of ammonia, which replaces and is isomorphous with the potash (KO) and soda (NaO), has the structure NH<sub>4</sub>O, and contains six atoms, whilst they have but two each. Other cases of this nature occur; thus one atom chlorine (Cl) may be replaced by Mn<sub>2</sub>O; two atoms of lime (CaO), or the compound (CaO, HO) hydrate of lime containing four atoms, are isomorphous, and capable of taking

the place of one equivalent of potash (KO) in a crystal, or of oxide of ammonia, which contains six atoms.

Another peculiarity of isomorphism is worthy of consideration, and calculated to impress the conviction that the manner and number in which the electro-positive and electro-negative bodies of a compound unite, have much to do with the resulting figure, although it does not afford a complete explanation of the mystery. There are a few cases of combination in the proportion of one atom of an electro-negative to seven of an electro-positive element; they offer a striking group, and are all *isomorphous*. The perchloric acid ( $\text{ClO}_7$ ); periodic acid ( $\text{IO}_7$ ); and permanganic acid ( $\text{Mn}_2\text{O}_7$ ) belong to this remarkable family. Iron and some other metals form two basic compounds; in one, the metal is combined with an equivalent ( $\text{FeO}$ ); in the other two, atoms of iron unite with three of oxygen ( $\text{Fe}_2\text{O}_3$ ); now these bases belong to different groups, and either with one that has a similar structure. Thus  $\text{FeO}$  is associated with  $\text{MgO}$  (magnesia);  $\text{CuO}$  (oxide of copper);  $\text{ZnO}$  (oxide of zinc), &c.; whilst  $\text{Fe}_2\text{O}_3$  is allied with  $\text{Al}_2\text{O}_3$  (alumina);  $\text{Cr}_2\text{O}_3$  (sesquioxide of chrome), and others of the same kind. In the following table of the most common isomorphous compounds (acids and bases), this truth will be rendered more apparent.

TABLE OF ISOMORPHOUS COMPOUNDS.

## BASES.

## Group 1.

Names.	Symbols.	Remarks.
Potash . . .	KO	Potash and oxide of ammonium are truly isomorphous, not only in their compounds, but in their action as salts towards other saline bodies, forming double salts, which are also isomorphous. Oxide of silver is associated with soda to a considerable extent. The hydrate of lime is related to potash.
Soda . . .	NO	
Oxide of ammonium . .	AmO	
Hydrate of lime . . .	$\text{CaO.HO}$	
Oxide of Silver . . .	AgO	

## Group 2.

Magnesia . . . . .	MgO	<p>These bases form salts, which, when in the same degree of saturation, and with the same amount of water of crystallization, have the same figure. The sulphates also combine with sulphate of potash, and form double isomorphous salts.</p>
Lime (the rhombohedral form) . . . . .	CaO	
Protoxide of iron . . . . .	FeO	
“ “ manganese . . . . .	MnO	
“ “ zinc . . . . .	ZnO	
“ “ cobalt . . . . .	CoO	
“ “ nickel . . . . .	NiO	
“ “ copper . . . . .	CuO	
“ “ cadmium . . . . .	CdO	
<p>The protoxide of lead may also belong to this group PbO</p>		

## Group 3.

Names.	Symbols.	Remarks.
Baryta . . .	BaO	This is a highly natural group, these oxides occurring frequently associated in minerals. The lime is of the form in which it occurs in argonite.
Strontia . . .	SrO	
Lime . . .	CaO	
Oxide of lead . . .	PbO	

## Group 4.

Peroxide of iron . . .	Fe <sub>2</sub> O <sub>3</sub>	These are all sesquioxides and isomorphous, replacing one another in whole or in part in the varieties of alum and other bodies.
Sesquioxide of manganese	Mn <sub>2</sub> O <sub>3</sub>	
Sesquioxide of chrome	Cr <sub>2</sub> O <sub>3</sub>	
Alumina . . .	Al <sub>2</sub> O <sub>3</sub>	

## ACIDS.

## Group 1.

Sulphuric acid . . .	SO <sub>3</sub>	These acids contain the same proportion of base and oxygen, and from numerous salts which, when containing the same amount of water of crystallization, are isomorphous.
Telluric acid . . .	TeO <sub>3</sub>	
Selenic acid . . .	SeO <sub>3</sub>	
Chromic acid . . .	CrO <sub>3</sub>	
Manganic acid . . .	MnO <sub>3</sub>	

## Group 2.

Phosphoric acid . . .	PO <sub>5</sub>	These acids are both tribasic, and therefore form three sets of salts, all of which are perfectly isomorphous; they are also found replacing one another in minerals, and, according to Orfila, in the bones of animals.
Arsenic acid . . .	AsO <sub>5</sub>	

## Group 3.

Perchloric acid . . .	ClO <sub>7</sub>	This group produces isomorphous salts; it also presents us with an instance where two atoms Mn <sub>2</sub> may replace one of the other elements.
Permanganic acid . . .	Mn <sub>2</sub> O <sub>7</sub>	
Periodic acid . . .	IO <sub>7</sub>	

## Group 4.

Arsenious acid . . .	AsO <sub>3</sub>	The relations between arsenic and antimony are very intimate, but their isomorphism is rare. In this case, the arsenious acid is in its unusual crystalline form. These acids do, however, often replace one another.
Oxide of antimony . . .	SbO <sub>3</sub>	

## Group 5.

Stannic acid . . .	SnO <sub>2</sub>	These are found combined in the same crystals in minerals.
Titanic acid . . .	TiO <sub>2</sub>	

## Group 6.

Names.	Symbols.	Remarks.
Sulphuret of antimony .	$\text{SbO}_3$	} The first two are sulphur acids, and all exist united in minerals.
Sulphuret of arsenic .	$\text{AsO}_3$	
Sulphuret of bismuth .	$\text{Bi}_2\text{O}_3$	

Whilst it is sufficiently apparent from the foregoing, which represent the cases in which compounds are undoubtedly isomorphous, that one substance may belong to two groups without possessing dimorphism, yet there is such a striking resemblance apparent in the entire combinations of some elements, that many chemists recognize isomorphous groups among elementary substances. Thus we find chlorine, iodine and fluorine, which have no known connection by form, inasmuch as fluorine has never been obtained in the elementary state, and chlorine is known only as a gas, remarkably similar in the numerous compounds they form with other elements. Thus chlorine, with hydrogen, forms an acrid gaseous body; so do iodine, bromine and fluorine. With similar proportions of oxygen, they form analogous acids, and those relating to the metals are similar. But we find chlorine in an isomorphous group with manganese, whilst bromine and fluorine have no such affinity. So iron is found associated at one time with magnesia and copper, and at another with alumina and manganese. There are, then, great difficulties in arranging the elements in isomorphous groups; but we are to regard the cases of discrepancy adduced rather as exceptions to a law, than throw away the advantages arising from attempting this classification. For, if we can attain it, the study of chemistry is simplified to an inconceivable extent, as we learn by inspection the chemical history of a family of elementary bodies, with their thousands of compounds, instead of having to investigate each separately, and without means to assist us in remembering them by points of connection. In the following table, the elements are placed in groups, according to the views of Prof. Graham. The classification is only to be regarded as an approximation; but imperfect as it may be, it affords one of the most sublime generalizations in science. Thus we find in the same group phosphorus (P), arsenic (As), antimony, (Sb), and nitrogen (N). Let us take a view of these compounds, to see whether this connection is intimate; and first with oxygen, they are as follows:—

P	As	Sb	N
$\text{P}_2\text{O}$	"	"	"
PO	$\text{AsO}?$	"	NO
"	"	"	$\text{NO}_2$
$\text{PO}_3$	$\text{AsO}_3$	$\text{SbO}_3$	$\text{NO}_3$
"	"	$\text{SbO}_4$	$\text{NO}_4$
$\text{PO}_5$	$\text{AsO}_5$	$\text{SbO}_5$	$\text{NO}_5$



The compound  $P_2O$  is rather doubtful, and the fly-oxide  $AsO$  has not been analyzed. In other respects, the group presents us with striking points of similarity; they all form powerful acids with  $O_5$ ; the compounds with  $O_3$  are also acid except in the case of antimony, which is a pseudo-base; with this exception, none of the elements form with oxygen bases at all. Again, we find that all combine with three atoms of hydrogen, forming the bodies  $H_3P, H_3As, H_3Sb, H_3N$ ,—all of which are pungent, poisonous and gaseous bodies, acting the part of bases. With the haloid bodies they unite in the proportion of one atom to three and five; and if we had a full history of these bodies, we doubt not that they would be found very similar in their properties. With metals they all unite as electro-negative substances, and there is some connection between their equivalent numbers.

#### ISOMORPHOUS GROUPS.

GROUP 1.	Strontium,
<i>Haloid bodies.</i>	Lead.
Chlorine,	GROUP 5.
Iodine,	Silver,
Bromine,	Sodium,
Fluorine,	Potassium,
Cyanogen.	Ammonium.
GROUP 2.	GROUP 6.
Sulphur,	Magnesium.
Selenium,	Manganese,
Tellurium.	Iron,
GROUP 3.	Cobalt,
Phosphorus,	Nickel,
Arsenic,	Zinc,
Antimony,	Copper,
Nitrogen.	Cadmium,
GROUP 4.	Aluminum,
Barium,	Cromium,
	Calcium,
	Hydrogen?

In generalizing on the subject of isomorphism, it is not to be overlooked that the electric affinity of a substance, and especially an element, is not a fixed property thereof, but changeable, and that this condition is more influential than any other thing in determining the replacing action of a body. Thus chlorine and hydrogen have, under ordinary circumstances, different electrical affinities, chlorine being decidedly electro-negative, hydrogen powerfully electro-positive, and for this reason called a metal. Yet we find that chlorine will frequently take the place of hydrogen in organic compounds, without disturbing the state of aggregation. This, we conceive, arises from the fact that these elements

differ widely in one *allotropic* state, and much less so in the other, or perhaps that  $\beta$  chlorine may resemble in its electrical relations a hydrogen, or *vice versâ*.

*Relations of Isomorphism to Physiology and Therapeutics.*—The study of isomorphism is one of the most important in chemistry, not only in assisting us to assort the elements and their compounds into families, and enabling us to detect impurities in crystals, &c., but likewise in pointing out connections in the sensible properties of bodies, in their substitution in plants and animals, and in their medicinal effects.

Allusion has already been made to the similarity in figure and sensible properties of the group of alums; these are all styptic, and their constituents obey the decomposing action of the same reagents. In chlorine, iodine and bromine, especially the two latter, we have a set of elements existing together in the ocean, forming similar acids and haloid salts, acting as substitutes, and so far as they have been employed as medicines, having the same therapeutic effects. We thus infer with confidence that the bromide of potassium is a substitute for the iodide of potassium, (hydriodate of potash,) which has become very much more expensive during the last few years.

In the vegetable kingdom, the history of these substances is complete, and highly important to agriculture. Thus, we find the oaks and willows, which are remarkably advanced in their development, by the presence of salts of potash in the soil, also benefited by soda, lime and oxide of ammonium, which are isomorphous, but refusing to grow where these are absent. The potashes of commerce are obtained in considerable amount from inland oaks; if we attempt to wash the ashes of those grown on the sea coast, we find soda chiefly, because, the salt being at hand, they are abundantly supplied with that base. But the substitution, so far as is known, is confined to the isomorphous bodies. It is also to be remembered, that these mineral substances are of the first consequence to the growth of the plant, which cannot exist without them. The different parts have different saline matters, and however well the stem may grow, no fruit will be formed unless the substances appropriate to that part are also supplied by the earth, or in manures. The economy and substitution of manures, therefore, depend on the isomorphism of the saline bodies.

The therapeutic effects of many compounds are also connected with their isomorphous relations. The sulphates of copper, zinc and iron, are active emetics in the dose of twenty grains, and efficient tonics in small doses. Many salts of potash, soda and oxide of ammonium, may be employed for one another in some cases, and produce similar effects, when the salt used has the

same acid. The doses in which the different preparations should be employed, are, however, often different, and their effects will usually depend upon their solubility, as well as their isomorphism.

Dr. Blake has made a long series of important experiments on the effects of isomorphous bodies, injected in solution into the veins and arteries of dogs, and has deduced the consequence that they act similarly, but in different doses. He employed compounds of twenty-eight elementary bodies. The action on the pulmonic capillaries and systemic or arterial capillaries, were particularly observed by the use of Poisseuille's hæmadynamometer, which indicated increased pressure in the arteries when there was obstruction to the circulation, and diminished pressure when it was rendered faster in the capillaries.

Some bodies, as the salts of strontia, baryta and lead, soon diminished, and, finally, destroyed the heart's action, acting in ten seconds after introduction. The salts of silver and soda, on the other hand, augment its irritability. The salts of lime, iron, zinc, manganese, cadmium, copper and nickel, rendered its action slower in small doses. The hydrochloric, hydrobromic, hydriodic acids, and other acids of iodine, bromine and chlorine, have an extraordinary effect in impeding the action of the arterial capillaries, causing the pressure in the hæmadynamometer to rise from two inches, which is the normal, to even eight inches. The salts of ammonia and potash also impede this circulation, whilst those of iron, zinc, copper, nickel, manganese and cadmium, increase it. Some substances obstruct the passage in the venous or pulmonic capillaries, whilst they do not affect the arterial capillaries, as the salts of strontia, baryta and lead, and the phosphoric and arsenious acid, and salts of antimony. The salts of silver and soda impede the circulation in both.

To state merely, that investigations of this nature are important, is to exhibit an ignorance of their immense value. Let them but be sustained by the concerted action of several experimenters, and we have a rational basis for therapeutics, in which science the darkness of chaos now exists. We can trust many of the above facts, because they satisfy observations made in a less direct manner, and they amplify our knowledge where it is most obscure. Take the action of antimony—*it arrests the circulation in the pulmonary capillaries*—here is a complete and luminous exposition of its therapeutic properties. It hinders the venous blood from becoming arterialized as rapidly as in the state of health. Who can be astonished after this, that it should reduce the activity of the animal, that it should prostrate in a few minutes and almost stop the action of the heart—for the patient is half asphyxiated. This is not the place to apply the doctrine, but the student will perceive that the facts of Dr. Blake form a strong

argument in favor of the theory, that the circulation of the blood depends upon its chemical relations to the capillaries. To this point, we shall refer in the chapter on the capillary force.

Another fact is apparent in Dr. Blake's researches,\* that the amount of any salt acting in the blood, is much smaller than persons suppose. We have it asserted, that nitre and other bodies pass into the blood in drachms, and the inference is general, that it remains there some time in these quantities; but in these experiments, five grains sufficed to kill a dog, when injected directly into the veins. So most medicines produced death in doses under sixty grains, and in very few cases were two drachms required for this purpose. Medicines enter the system by absorption only when they are exhibited in a diluted state, and then but little enters in comparison with the amount refused.

#### THE PRODUCTION OF GROUPS AND TYPES.

In the same way that the chemical force determines the crystalline figure of inorganic bodies, it arranges the molecules of organic substances, imparting to them specific forms and properties. As there is not a crystalline adjustment given to the particles of vegetable and animal matter, the peculiar form is termed a *group*. This term implies a certain arrangement of the atoms—a grouping of them.

Another peculiarity exists in some organic bodies—the cellular figure: not only are the atoms grouped after a system, but an obvious arrangement of the compound molecule is made; it is enveloped in a spherical case, or may be arranged into a spherical cell, which forms the characteristic figure of the body. Starch is an instance of the first kind; it consists of spheres which are cells, the interior of which is filled with amidine. The entire cell is insoluble, the interior is soluble in cold water. The hollow cell is more complex; this usually contains organic matter, combined with certain saline substances, of which the sulphates, silicates and phosphates, are the chief—the properties of the cell depending upon its components.

We have, therefore, a remarkable tendency in organic compounds to assume definite figures, as in the salts, but they are spherical rather than angular. The forms of some are obvious to the microscope, as in the case of cellules, but in others, the figure is hidden. In the latter case, the molecules are said to be grouped, or to be arranged according to a type or model. The type is both mechanical and chemical; the former refers to the number of atoms, the latter to similarity of property without reference to the number of atoms.

\* See *The American Journal of the Medical Sciences*, for January, 1848, p. 63, *et seq.*



The subject divides itself into three parts, which may be put as questions. 1. What is meant by organic grouping? 2. What is a mechanical type? 3. What is a chemical type?

1. *What is meant by Organic Grouping?*—Animal and vegetable bodies are remarkable for the great number of atoms they contain. It has already been remarked, that fibrine has 1042 atoms; starch and a number of similar bodies have from 32 to 40 atoms; in such cases, the force of chemical affinity must be feeble, and the arrangement of so many molecules subject to great disturbance. Hence we find that the same atoms may give us either starch or dextrine; one a soluble, the other an insoluble body. Other cases of this kind have been alluded to under the topic of *Isomerism*. Now what makes the difference in their properties? In most cases it will depend upon the manner in which the atoms are arranged or *grouped*; in others it may depend upon allotropic differences in the elements.

What is meant by difference in grouping? Let us suppose twenty atoms of the three elements, carbon, hydrogen, and oxygen, to be free to combine by the chemical force. It is obvious that they may be arranged into a sphere; they may be aggregated into a cube, into a bar, or any modification of these. And the question, how can a determinate force, like chemical affinity, act so diversely, does not reach the case; for, as we have shown under the section on dimorphism—heat, light, and other forces may be acting simultaneously with the disposing chemical force. We have seen, that different figures are given to inorganic bodies by the action of heat, and that light and heat are connected with the production of allotropic differences. Now, organic compounds are remarkably changed by heat and light. Without light, the woody matters, and the green coloring bodies of plants, cannot be formed; without heat, the fats, urea, and other products of the animal, could not come into existence. Difference of grouping may then spring from the disturbing action of light and heat; the action of which is to affect the rearrangement of the molecules, and give the mass new properties. The ancients indulged an hypothesis, that the different qualities of sweetness, sourness or bitterness depended upon the forms of bodies, and their relations to the organ of taste; this cannot be proved by inspection, but modern chemistry has satisfied us that the sensible properties of bodies do depend on the arrangement of their molecules.

A few illustrations will make this apparent. Formiate of methylene (*Kane*) and glacial acetic acid, when analyzed, both yield four atoms each of carbon, hydrogen, and oxygen, or have the formula  $C_4H_4O_4$ , yet they are different in every property. But if we try the action of reagents on these, it will soon be found that by several means the acid can be resolved into  $C_4H_3O_3+$



HO, for in the place of the HO, other metallic oxides may be substituted; this, then, determines that the atoms are grouped into two sets, one of which, the  $C_4H_3O_3$ , is more fixed in the body than the HO. Again, the formiate can be resolved into  $C_2H$ ,  $O_3 + C_2H_3O$ , a complex body containing four parts,  $C_2H$  being *formyle* with  $O_3$  or formic acid, and  $C_2H_3$  being Dr. Kane's methylene with O, or oxide of methylene. Oil of turpentine and oil of citron, when analyzed, yield the same formula  $C_4H_5$ ; but in their reactions they exhibit a difference of grouping, the first combining as  $C_{20}H_{16}$ , whilst oil of citron combines as  $C_{10}H_8$ .

The two cases selected, exhibit instances of *metameric* and *polymeric* compounds. In the first, there is difference of grouping with similarity in the number of atoms; in the second, the elements and proportionate number of atoms are similar, but not the same, one compound having double the number of atoms of the other.

The sensible properties of a body may, therefore, be changed by a cause which will throw the atoms into new groups. The chief of these causes is heat, by means of which most of the compound organic bodies are altered without any loss of their substance.

*What is a Mechanical Type?*—Numerous organic bodies are found to contain the same number of atoms, but of different elements. The frequent occurrence of a certain arrangement of atoms, awakens a suspicion that it is not merely accidental, but a model or type which represents a stable molecular aggregation. And, as we judge by the number only, without reference to the properties of the body, it is simply an *arithmetical* or mechanical coincidence that affects us, and hence it is called a *mechanical type*. This would be curious in the study of the habitudes of molecules, if it went no farther. But it is connected with an extraordinary fact, viz: that the elements can be changed, more or less entirely, without the number of atoms being altered. According to Dumas, one element may displace any other, however dissimilar in its electrical relations; but we have already remarked, that the electrical condition of the replacing body may vary. This constitutes the doctrine of *substitutions*, in which it is asserted that one element can replace every other in a mechanical type without altering its numerical form.

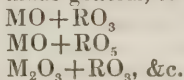
An illustration will serve to explain this more clearly; the group of atoms,  $C_4H_6O_2$ , representing alcohol, is a mechanical type containing 12 atoms; when this substance is subjected to the influence of oxygen, it is converted into acetic acid,  $C_4H_4O_4$ , which has also 12 atoms, and in some other changes which it undergoes, this number remains fixed. It would appear that for this

class of substances, twelve atoms are essential to build up the compound molecule. In the change from alcohol to acetic acid, the elements remain the same ; but there is an increase of atoms of oxygen and diminution of hydrogen ; two atoms of oxygen are substituted for two of hydrogen ; this is not a usual thing, but in the following compound, chlorine is substituted for hydrogen.

When the crystallized or glacial acetic acid is exposed to the action of chlorine *in the bright sunshine*, action ensues, and the formula  $C_4H_4O_4$  becomes converted into  $C_4HCl_3O_4$ , or chloro-acetic acid. In this case, the mechanical type of twelve atoms is retained, and three atoms of hydrogen are displaced, or substituted by three of chlorine. As hydrogen and chlorine are dissimilar in their electrical relations, this and similar cases appear to be opposed to the electro-chemical theory (p. 101) ; but it is not to be overlooked that the change occurs only in bright light, which we know has the power of changing the  $\beta$  allotropic state of chlorine into the alpha, or converting inactive into active chlorine ; and it is more probable, as Dr. Draper suggests, that the replacement is due to this disturbing cause, than that the electro-chemical theory is in error.

Another extraordinary instance of the permanence of a mechanical type under substitution, is seen in the history of the compound  $C_4H_5Cl$ , or chloride of ethyle ; when acted on by chlorine, it changes through the following bodies— $C_4H_4Cl_2$ , an oily body— $C_4H_3Cl_3$ , a liquid— $C_4H_2Cl_4$ , then  $C_4HCl_5$ , and finally  $C_4Cl_6$ , or sesquichloride of carbon. Here every atom of hydrogen is step by step displaced, the same numerical type of ten atoms remaining throughout, even when it ceases to be a compound of three elements, and contains only two,  $C_4Cl_6$ .

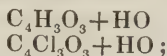
But the permanence of a certain number of atoms throughout a series of compounds is neither rare, nor confined to organic chemistry. The common salts of the same group contain a type, the expression of which made general, is as follows :



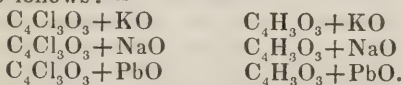
In which M is a metal, O oxygen, and R an acid radical. The first  $MO + RO_3$  is the type for the protosulphates, arsenites, seleniates, &c., the acid of which is in  $O_3$ . The second formula contains the protonitrates, phosphates, arseniates, antimoniates, and acids in  $O_5$ . The third type contains the peroxides of metals, and contains as many classes as there are different types in the acids.

*What is a Chemical Type?*—A chemical type differs from the mechanical or numerical type in this extraordinary circumstance, that the number of atoms is not only the same throughout the series, but the chemical properties also. In the case of  $C_4H_4O_4$ ,

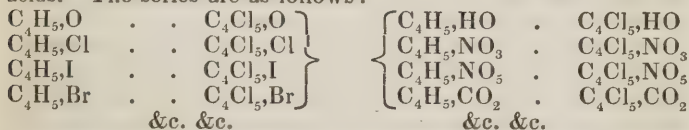
or acetic acid, given in the foregoing paragraph, the action of chlorine produces  $C_4HCl_3O_4$ , or chloracetic acid, not only remarkable in its form, but having very similar properties. Thus their grouping is alike :



they are both strong and volatile acids, both monobasic, that is, combine with but one atom of base, which becomes a substitute for the HO, as follows :—



Chlorine ether,  $C_4Cl_5O$ , is obtained by the substitution of chlorine for the hydrogen of common ether  $C_4H_5O$ ; the mechanical type, ten atoms, is the same; but their chemical type is also identical. They are both ethers, are bases, and form analogous salts, both by direct combination with the haloid bodies in the substitution of the O, by Cl, I, Br, &c., as well as in their union with HO (water or hydric acid), and combination with other acids. The series are as follows :—



In these cases the parallelism is extraordinary, and we are compelled to admit that the unchangeable terms of these compounds, the  $C_4H_5$  and the  $C_4Cl_5$ , are united together or grouped more perfectly than the other terms. Neither of these is known, but notwithstanding this, their permanence proves their existence, and they are designated *compound radicals*. The first,  $C_4H_5$ , is termed ethyle, and has the symbol  $\overline{Ae}$ , the other may be termed chloryle, and represented by the symbol  $\overline{Cle}$ .

#### CATALYSIS.

*The Propagation of Chemical Action—The Action of Presence.*—In the preceding cases, we have been studying the chemical affinity, as it exists between atom and atom only. In treating of combining numbers or equivalents, it has been stated that a given number of grains of acid neutralize a precise amount of base. For instance, ten equivalents of the one may unite with ten of the other, and then all action ceases, and this is the case whatever may be the excess of either body. But there are numerous cases which seem to offer exceptions to this rule, in which we find that

several pounds of matter may be chemically changed by the introduction of a minute quantity of an active agent. Take the instance of fermentation: a little yeast is added to hundreds of gallons of wort, and the sugar and albumen there are changed throughout the whole. A chemical action, started at a point by the yeast, travels throughout the whole; step by step it invades the bulk, and atom after atom of sugar, &c., yields to the force. This is a case of the propagation of chemical force. Liebig goes further, and attributes the propagation to movements set up among the molecules. It is also called catalysis, and action of presence, the latter term indicating that the presence of a body disturbs the chemical relations of the molecules present.

Instances of change by catalysis are not confined to organic bodies, although they are very frequent among them. If a highly porous body, as spongy platinum, be introduced into a mixture of oxygen and hydrogen gases, it condenses a portion of them in its pores, and presenting them to one another, in a new state, effects a slow union. Finely divided platinum called platinum black, and pure platinum, effect numerous catalytic changes, and are in no case acted on in the least degree, but appear to operate by condensing some gas in nearly every case.

It has already been stated, that the oxygen and hydrogen have an *alpha* or nascent state, in which they are condensed, and, perhaps, fluid; and it is probable that the forms of platinum have the property of so far condensing them, as to produce, little by little, this state. Union, in the presence of this metal, is always slow. In this case, catalytic action arises from a change in the activity of an important agent, and it may be said to be an instance of *catalysis resulting from capillary action*—the oxygen or hydrogen gases being condensed by the metal in virtue of their capillary affinities.

Another cause of catalytic action, is the disturbance of the molecular state of the atom by a force. The gases, oxygen and hydrogen, touched with a point of flame, or with the electric spark, unite explosively. The atoms immediately acted on are not merely affected, but an influence is propagated, with the speed of lightning, through the mass, however great. It has been shown that the chemical and electrical forces are identical, and that heat can produce electrical excitement. The nature of induced electrical action has also been explained. In such cases, the effect is obviously due to the influence of heat or electricity, and we may conceive that either of these forces induces a polar state throughout the gas, which is favorable to the union of the atoms. In the gaseous state, the atoms are repelled either as an original state, or as the result of the action of a repulsive force, and in uniting this is suddenly neutralized. Light produces similar effects, both rapidly as in the union of chlorine and hydrogen, or



slowly as in the decomposition of ammonio-citrate of iron, and other bodies. Heat produces numerous catalytic effects of the same nature. These present us with illustrations of *catalysis arising from the disturbing effects of heat, light, and electricity*.

Fermentation can only take place where there is oxygen, and is never spontaneous, except in bodies having a very unstable composition, as fibrine, albumen, &c. Once begun, the farther presence of oxygen is unnecessary, and the ferment can propagate its action to substances of a less complex nature, and even cause the union of some gaseous mixtures. Something very analogous to a current of electricity, producing decompositions and recompositions, appears to be started in the mixture, which is capable of acting even on foreign bodies as a force. Instability of grouping, arising from feebleness of chemical affinity, is the necessary condition of spontaneous fermentation, which we may regard as a change occurring in consequence of the development of new and stronger affinities, by the action of oxygen, heat and other causes, which produce a new aggregation of the atoms. Heat, in destructive distillation and in other ways, produces catalytic effects of a similar kind. This, then, is a form of *catalytic action resulting from chemical disturbance*.

There are other cases in which the cause is less apparent; thus a little sulphuric acid converts a boiling solution of starch into dextrine, and ultimately into grape-sugar. There is change of grouping in these bodies, as well as an increase of atoms, starch having the form  $C_{12}H_{10}O_{10}$ , and grape-sugar  $C_{12}H_{14}O_{14}$ , so that the action here does not increase, but rather diminishes the chemical force of aggregation.

Catalysis is, therefore, not a single action, but the result of many, and may arise as a consequence of the condensing action of a body upon an important element—from the disturbance of chemical affinity by other forces, as light and heat—from the action of a powerful agent, as oxygen on bodies having an unstable grouping, as in fermentation, by which compounds of a more permanent character are produced; or, lastly, the cause may differ from the preceding, and be obscure. In all cases, however, we have a propagation of force, which can be arrested, or directed into new compounds by proper means. This ability of the chemical force to develope itself in the manner of a current, or, by producing polarity, associates it with the electrical force in a striking manner.

In the chapter on fermentation, and under their appropriate heads, we shall enter more fully into the causes of catalytic action.

In several points of view, the study of catalytic action is of great importance to the physician. For he will find that, in the



chemistry of the animal and vegetable world, it is the paramount force. In these, instead of the complete decomposition of bodies, or their sudden formation by the union of their several atoms, there are steps of change subject to the disturbing action of heat and light. Thus, the proteine compounds of the body form oxides, then resolve themselves in numerous products representing the tissues, and, finally, become transformed into urea, water and carbonic acid; the former of which, when excreted from the body, is further changed into carbonate of ammonia and water. These are all catalytic actions, in which a few atoms of oxygen and a certain temperature are the necessary conditions. In the plant, albumen does not come into existence by the synthetic union of so many atoms of its various elements, but is the result of a series of changes, commencing with the decomposition of carbonic, sulphuric and phosphoric acids, and other bodies.

In disease, a morbid action commencing at a spot may pervade the body; the vaccine virus is an illustration. Contagious diseases belong to this category. Morbid growths, tubercles, carcinoma, &c., have their cause in perverted chemical action, and their development in catalysis.

In therapeutics, many medicines will be found to act catalytically. This is especially true in those which act through the circulation; a grain or two of tartarized antimony so alters the chemical relation of venous blood to the pulmonary capillaries, that it can scarcely pass through them, whilst iron quickens its flow in the systemic capillaries. The change of relation in the blood is of the same kind as the change in chemical properties produced by uniting certain bodies. Thus platinum is not in the least acted upon by strong nitric acid; but if mixed with silver, it readily dissolves in weak acid. Mercury has no affinity for ammonia; but if it be alloyed with a very minute quantity of sodium, they unite completely, and there is formed the amalgam of mercury and ammonium. Many instances of this kind exist, and the amount of disturbing body does not, in some cases, exceed  $\frac{1}{2000}$  of the bulk; hence it is not to be wondered at, that the introduction of some of the chemical agents used in medicine should alter the electrical relations of the blood—especially as its most important component, albumen, is subject to the action of nearly every metallic salt, and influenced by both acids and alkalies.

In the metallic mixtures alluded to, the inactive bodies platinum and mercury, have their electrical affections entirely subverted, and some medicines do unquestionably produce the same action on albumen; otherwise it could not be influenced by so many substances. The cause of the capillary circulation, which is the only important portion of the circulation, is chemical, and

depends upon the electrical relations of the fluid and tissue; if these be abnormal, it must be impeded, and may be arrested. It may also be exalted by other agents.

The glands are centres of peculiar catalytic action, where a peculiar aggregation is given to certain components, usually effete, of the circulating fluid. It may be well here to adduce a case of definite catalytic action. The propagation of force may be *ad infinitum*, or it may be restricted; the explosion of gases by heat is an instance of the first, the conversion of starch into sugar by diastase of the second. In the latter, one part of diastase (a ferment) is capable of changing two thousand parts by weight of sugar; it is, therefore, definite, for if the sugar be in excess, no more will be converted. So the glands exercise a determinate catalytic action, which is not like that of a contagious poison, operative on all the blood, but on a portion. The saliva, the pancreatic fluid, the gastric juice, and some portion of the bile, are instances of this change. But the kidneys, mammæ, and uterine glands seem to separate their secretions from the blood without producing any change on them.

These imperfect remarks are placed here for the purpose of arousing the attention of the student, rather than satisfying his curiosity. My object being to induce him to master a subject, which, at the first sight, he might regard a specimen of chemical refinement and generalization, rather than of practical value. In the subsequent chapters, frequent allusion will be made, and many arguments founded on the truths of catalysis adduced, which will be scarcely intelligible to those ignorant of the habitudes of this variety of the chemical force.

## PART II.

### THE SIMPLE BODIES OF GREATEST IMPORTANCE.

A TABLE of the elements is given at page 135, in which they are divided into metallic and non-metallic bodies, and their electric affinity indicated. It would be more consistent with theory to treat the electro-negative substances first, or to place them in isomorphous groups, but for the convenience of the learner another plan has to be employed. The most active elements are placed first, so that in treating of the compounds of such as follow, the student may know the properties of the bodies referred to. Where it is possible, I shall throw the elements into isomorphous groups to save needless repetition. Such bodies as are of the highest interest to the physician and student of organic nature, will occupy our time chiefly; the rest will be merely mentioned. So soon as we have gone over the elements important to animal and vegetable chemistry, we shall enter on the subject of organic chemistry, recurring to the metals and salts in the last portions of the work.

### OXYGEN.

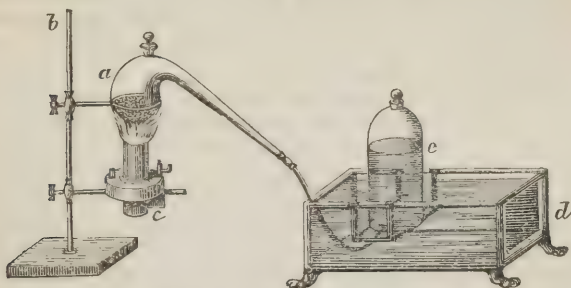
*Synonyme*, Vital air. *Symbol*, O. *Equivalent*, 8.

COMMON oxygen is a gas resembling air, but is also known in a much more active or *nascent* state. The gas is, according to the modern nomenclature, termed *beta* ( $\beta$ ) oxygen, and in the nascent state, when it is probably liquid, *alpha* ( $\alpha$ ) oxygen; the symbol is O.

It is the most abundant body in nature, but does not exist uncombined; hence, to obtain it pure, we must resort to artificial means. It may be procured by heating many of its compounds, as some of the *oxides*, as of mercury, manganese—or nitrates, chlorates and other substances, in which it is abundant. A ready method of obtaining it in a pure state, is to heat chlorate of potash in a retort *a* over a large spirit lamp *c*. The gas is evolved by the decomposition of the salt, and is to be collected in a vessel filled

with water *e*, and inverted in a small cistern or pneumatic trough *d*. The manner of the arrangement is seen in the figure.

Fig. 48.



The chlorate of potash has the formula  $\text{KO} + \text{ClO}_5$ , and is decomposed by the heat, becoming  $\text{KCl}$ , and the oxygen ( $\text{O}_6$ ) passing off as gas. A little black oxide of manganese, added to the chlorate, enables us to obtain it by the use of much less heat.

*Characters.*—It is colorless, inodorous, and tasteless, specific gravity 1.111, air being 1.000; 100 cubic inches weigh about 34 grains. It is permanently elastic in the free state, having never been condensed by cold or pressure. Water absorbs about 4 per cent. of this element; it is also found in arterial and venous blood in the uncombined state, being in larger quantity in the first.

*Properties.*—As a gas it is a very active substance, but in the *alpha* state it is the most active in nature. It combines with every element except fluorine. Its basic compounds are called oxides; it also enters into the composition of acids, and was formerly called the acidifying principle. Without its presence, ordinary combustion is impossible, and, for this reason, it was thought the universal supporter of combustion; but chlorine, iodine, sulphur and other bodies, are sometimes equally active.

It is, however, the sole supporter of respiration, for without it all animals would die; but for this purpose the pure gas is too active, and requires dilution. In the atmosphere we are presented with a suitable mixture for this purpose, consisting of 20.8 parts of oxygen with about 79.2 of nitrogen. In pure oxygen, animals are at first excited, but presently die of over stimulation. The oxygen gas inhaled with air is partially condensed by the mucous membrane of the air cells of the lungs, and thus presented to the blood in a highly active state. Oxygen is, under all circumstances, an electro-negative element.

Numerous striking illustrations of the rapidity of its chemical action may be given: thus a piece of burning phosphorus, sulphur,

or Indian rubber plunged in it, emits an intense light. Iron wire made red hot at one end and placed in it, burns with brilliant scintillations. If it be collected under pressure in a metallic vessel, and made to issue by a jette through the flame of a spirit lamp, a blowpipe flame of intense heat is obtained, which will melt most metals, and produce a brilliant phosphorescence in lime, magnesia, and other bodies.

In the changes of organic matter, oxygen is an important body; it seems, in all cases, to act the part of a destroyer, reducing complex substances to simple forms. In the human body, its office is to reduce the fats and proteine of the system to urea, carbonic acid, water and choleic acid, destroying their nutritious properties. As a therapeutic agent it has not been fairly tried, but mixed with air, in the proportion of 1 part in 6 or 8, has been used to resuscitate persons asphyxiated by vapor of ether, and would be serviceable in other cases of suspended animation; but in these protoxide of nitrogen is superior in efficacy. Under that gas, further remarks will be found on the subject.

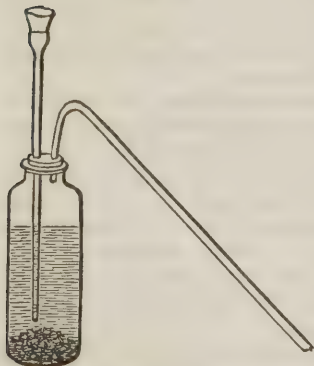
## HYDROGEN.

*Symbol, H. Equivalent, 1.*

THIS element does not exist in the free state in nature, and is most developed in water, which contains  $\frac{1}{8}$ th of its weight of hydrogen. It is procured artificially as a gas, its *beta* form; in the *alpha* state it is intensely active, and is probably a fluid.

The readiest way of obtaining the gas, is by pouring dilute

Fig. 49.



sulphuric acid on strips of zinc placed in a suitable bottle, furnished with a tube to discharge the gas under water, so that it may be collected in the same way as oxygen. The figure (49) represents a convenient apparatus for obtaining small quantities. In this process, water (HO) is decomposed, the oxygen combines with the zinc, and the hydrogen is made free; the sulphuric acid now combines with the oxide of zinc to form its sulphate.

*Characters.*—The pure gas is inodorous, colorless, and tasteless; it is the lightest known element, its specific gravity being



0.0694; 100 cubic inches weigh 2.1 grains. It is scarcely soluble in water, and has not been liquefied by pressure. It is a powerful refractor of light as compared with other gases.

*Properties.*—Hydrogen gas is highly inflammable, but not a supporter of combustion. An excess of this body frequently endows its compounds with inflammability as in coal gas, oils, rosin, wax, alcohol and ether. It is electro-positive, and its chemical habitudes are those of a metal; indeed, it is isomorphous with magnesia, lime, zinc, copper, &c. The fact of its gaseous form is no obstacle to this view, for mercury is a fluid, and readily volatilized.

In the modern theory of saline substances, called the *binary theory*, hydrogen is treated as the active agent of most acids. See *nitric acid*. Mixed with oxygen in equal parts, or with air in the proportion of 1 to  $2\frac{1}{2}$  parts, it forms a violently explosive compound, when acted on by the electric spark or by heat, the product of the action being water. Spongy platinum condenses hydrogen to such an extent as to become red hot by the evolution of its latent heat. It is irrespirable, but not poisonous, and will be found a constituent of nearly every organic body, whilst with the exception of water it is rare in the inorganic world.

*Uses, &c.*—Its levity suggested the employment of the gas in filling balloons, and it is the best agent for this purpose, but too expensive; common coal gas, which is a compound of hydrogen with carbon (CH) is now used. It is of no physiological interest, except that if inhaled, it produces a remarkable effect on the voice, reducing its volume to a whisper.

The heat of its flame, when burning in air, is very high; and this fact induced Professor Hare to make experiments on the use of hydrogen as a source of intense heat when burnt in an atmosphere of pure oxygen. In this way was originated his famous hydro-oxygen blowpipe, now extensively employed in the arts. This instrument consists of two reservoirs, containing the gases oxygen and hydrogen in the separate state, and under considerable pressure; and a metallic tube passing from either to a jette of a particular construction. The jette is made by stuffing a stout tube with fine wire, and then passing it through a drawing plate as in the manufacture of wire; by this means the whole becomes compact, the intervals between the wires becoming so minute, that the flame of the blow-pipe cannot travel backwards, and act on the gases. The flow of the gases is regulated by stop-cocks, the amount issuing being in the proportion of one volume of oxygen to two of hydrogen. The heat of the inflamed jette of gas is more intense than that of the fiercest furnace, and melts platinum, iridium, osmium, and other bodies formerly esteemed infusible.

The brilliant phosphorescence, occurring in lime and other

bodies when heated before this flame, has produced hopes that an improved means of illumination may be effected by its means. Lieut. Drummond's light, used in the light-houses of England, is derived from incandescent lime. In this case, a stream of oxygen is thrown upon the flame of oil or coal gas for the production of the heat.

*Compounds.*—Hydrogen has an extensive range of affinity; but we are only prepared to examine its compounds with oxygen. These are two, HO, or water, and HO<sub>2</sub>, the peroxide of hydrogen.

#### WATER—OXIDE OF HYDROGEN—HYDRIC ACID.

*Formula, HO. Equivalent, 9.*

Pure water does not exist in nature; in rains, rivers, and other sources, it always contains saline and gaseous matters. Rain water is the purest. It is obtained pure by careful distillation, and consists of one atom of hydrogen (H) united with one of oxygen (O); its combining number is therefore  $1+8=9$ . This composition may be proved by analysis, and by synthesis. If vapor of water be passed through a red hot iron tube, the iron unites with its oxygen, and hydrogen passes over. By the galvanic battery, water is decomposed into one volume of oxygen and two of hydrogen, or by weight 8 parts of the former to 1 of the latter. If these gases be now mixed and exploded by heat or the electric spark, they recombine, and form water again. This is the synthetical proof. The burning of hydrogen in air is always attended with the production of water.

*Characters.*—Pure water is tasteless, inodorous and almost colorless; sp. gr. 1.00 at 60° F.; 1 cubic inch weighs 252.45 grs. It boils at 212°, and solidifies into ice at 32° F. The sp. gr. of its vapor is 0.6201, and of ice at 32° 0.916. It is a good refractor of light, an indifferent conductor of electricity, and almost a non-conductor of heat. It is slightly compressible, diminishing but  $\frac{1}{22000}$ th in bulk by one atmosphere, but is elastic.

*Properties.*—It is one of the most extraordinary solvents, or to speak more precisely, it exerts a capillary affinity for most bodies. It dissolves numerous saline bodies, a portion of many gases, and exerts a great affinity towards the greater number of organic substances. In these cases its action is neutral.

Towards many acids it acts as a *base*; thus in strong sulphuric acid we find the presence of an atom of water, its formula being HO+SO<sub>3</sub>, and besides this there are three other compounds of sulphate of water. Nitric, phosphoric, oxalic, acetic and other acids, display the same structure. In these cases, the water is said

to be basic, and it acts precisely like any metallic oxide of the same group. Indeed, in producing salts of zinc, copper, &c., with these acids, the water salt is changed by the substitution of the metal for hydrogen,  $\text{HO} + \text{SO}_3$  becoming  $\text{MO} + \text{SO}_3$  (in which M is the metal) with the evolution of hydrogen.

With bases, on the other hand, it combines as an acid, *the hydric*, as in the hydrates of potash, soda, lime, baryta, &c., the formulas of which are  $\text{KO} + \text{HO}$ ,  $\text{NaO} + \text{HO}$ ,  $\text{CaO} + \text{HO}$ , &c.

In numerous crystalline bodies, it is an essential constituent, for when driven off by heat they become amorphous. In this case, it is called *water of crystallization*, and written Aq after the formula—thus crystallized oxalic acid is  $\text{HO}, \text{C}_2\text{O}_3 + 2\text{Aq}$ , in which the first term HO is basic water, and the last 2Aq indicates two atoms of water of crystallization. This may be driven off by heat, without changing the chemical properties of the body; whereas, any attempt to remove the HO, is attended with the destruction of the oxalic acid.

The combination of the elements of water is not of the most permanent kind, although the chemical union is stable, for water is readily decomposed by many metals, by some in the cold, as potassium, sodium, lithium, barium, calcium, &c., by others, as iron, zinc, manganese when red hot. In plants, it is continually decomposed, as well as in various processes of nature. On the other hand, it is equally readily formed whenever nascent hydrogen is presented to nascent oxygen, where there is no metal or other active agent present. In the human body, all the tissues are oxydized by the changes therein, and hydrogen being one of their chief components, is converted into water by this action.

*Uses.*—Its principal use is as a solvent in the arts, and as an essential substance to the existence of animals and plants. The bodies of animals consist of nearly  $\frac{9}{10}$ ths of water, and death is as certainly produced by its abstraction as by starvation; indeed, life cannot appear without water. As a medium for the dilution of medicines, and the employment of cold and warmth in diseases, it is also valuable.

*Peroxide of Hydrogen*— $\text{HO}_2$ .—This is very difficult of preparation, and cannot be kept; but is remarkable from possessing the action of a ferment, although a strictly inorganic body. It is dense, but like water, when heated, it evolves oxygen; at a high temperature, it does so explosively. Most metals introduced into it cause its rapid decomposition into water and oxygen, acting catalytically, and undergoing no change themselves; this action is sometimes attended with the evolution of much heat. But if we add the oxides of silver, gold or platinum, to the peroxide, they become decomposed also; thus the chemical decomposition of the fluid is propagated to the oxides in the same way as the

changes going on in yeast are communicated to a solution of grape sugar.

It also possesses bleaching and stimulating properties, but is of no practical value from the difficulty attending its preparation.

## NITROGEN.

*Synonyme, Azote. Symbol, N. Equivalent, 14.0.*

NITROGEN abounds in the atmosphere as a gas, combined with oxygen; this is its inactive or *beta* state, in which it is almost destitute of active properties; but it also exists in the *alpha* or nascent state, and is then one of the most active elements, and particularly in organic compounds, to which it is almost confined.

Gaseous nitrogen is readily procured for experiment, by burning a little phosphorus in a glass jar inverted over water. The air of the jar is a mixture of 4 parts nitrogen and 1 oxygen, which latter unites with the phosphorus to produce phosphoric acid, which is dissolved by the water. The remaining gas is therefore nitrogen, but is slightly impure.

*Characters.*—An inodorous, tasteless, colorless, permanent gas; sp. gr. 0.976; 100 cubic inches weigh 30.14 grs. at 60° F.; almost insoluble in water, 100 volumes taking up but  $1\frac{1}{2}$  of the gas. Its refractive power is also much less than that of hydrogen.

*Properties.*—As a gas, it is almost without properties, being neither inflammable, nor a supporter of combustion nor respirable; but it is not poisonous, and appears indifferent to nearly every agent. But in the *alpha* state it combines with avidity with oxygen and hydrogen. Those animal bodies, which are spontaneously fermentable, contain the largest amount of this body; the alkaloïds, strychnine, prussic acid, and many poisons, also contain it. The only substances capable of sustaining the life of animals or developing plants, are nitrogenized. Most of its compounds are unstable and readily decomposed; some, as the quadrochloride of nitrogen, are explosive.

*Uses.*—Gaseous nitrogen is not applied to any purpose in the arts; but in nature it serves to dilute the oxygen of the atmosphere, and render it fit to sustain the respiration of animals.

## THE ATMOSPHERE.

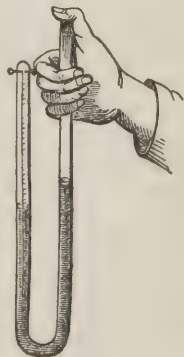
This is a vaporous shell, surrounding the earth, in which everything that is volatile is accumulated. It has an altitude of between 43 and 45 miles. Its main components are in the 100 volumes, 20.8 oxygen, and 79.2 nitrogen; or, by weight, 23.04



parts oxygen to 76.96 of nitrogen. It also contains vapor of water (see p. 39); carbonic acid, in quantity varying between 4 and 6 parts in 10.000; according to Liebig, one part in 70.000 of ammonia; and in particular situations, as over marshes, gaseous compounds of hydrogen, with carbon, phosphorus and sulphur have been detected.

*Analysis.*—The analysis of air offers a specimen of the examination of gases, and the process called *Eudiometry*. There are several means of conducting the investigation, but the following is most common. A given weight of the air or gas to be examined is first dried, by passing it through a tube containing chloride of calcium, into a vacuum formed in a glass vessel; the loss of weight indicates the moisture present. It may then be introduced into a graduated tube, over mercury, and half its bulk of pure hydrogen gas added. The tube used for this purpose is called Ure's Eudiometer, and is depicted in the figure. It is bent, and closed at one end; in the upper part of the sealed end are introduced two platina wires, one from either side, with their ends within a tenth of an inch from each other, for the purpose of allowing the electric spark to pass from one to the other through the mixture of gases. The central parts are filled with the fluid, and some air is left under the finger in the long leg to receive the shock of the explosion, which follows the union of the oxygen and hydrogen. When used, it is handled as in the figure, and the knob of the outer wire, brought in contact with the prime conductor of the electrical machine. The oxygen present unites with the hydrogen to form water, and a considerable deficit occurs in the gaseous volume, which is measured by reference to the graduated part of the tube, after sufficient mercury has been introduced to rise to the same height in both legs; one-third of the deficit is oxygen. The carbonic acid can only be determined when large quantities of air are used, by passing it through a solution of potash, and weighing the increase, which will be due to carbonic acid. Other means may be employed, but the above will be a sufficient illustration of the general plan of examining gases.

Fig. 50.



*State of Combination—Diffusion of Gases.*—In consequence of the proportion of oxygen being nearly  $\frac{1}{5}$ th, and nitrogen  $\frac{4}{5}$ ths, it was formerly thought that the air was a chemical compound of these elements, but in the present day, it is allowed on all hands to be a capillary mixture. The air has the properties



of its components ; its parts are readily separated, as is seen in every case of combustion, in which its oxygen is active. It possesses the bulk of its components without condensation, and their average weight and refracting power. Its specific gravity is the unit for gases and vapors, and 100 cubic inches weigh 30.14 grains.

But, it will be asked, what is a capillary mixture? It has been found that gases pass into one another without impediment, or, to express it in the words of Dr. Dalton, as into a vacuum. This is true, also, for vapors. When two or more gases, or vapors, are presented to one another, they mingle with great rapidity, and the resulting mixture becomes uniform, its bulk being the sum of the volumes of all. This takes place irrespective of their different densities, or other properties—thus carbonic acid, if confined in a vessel under hydrogen, will rise into it, and the hydrogen will descend, notwithstanding that the sp. gr. of the first is 1.524, and that of the second only 0.0694, or that one is 22 times heavier than the other. This phenomenon results from the extremely porous nature of gases, and the absence of the cohesive force in them, or is due to capillary affinity, and called the *diffusion of gases*. It is in virtue of their diffusiveness that the gases of the air are found in all places mingled in the same proportion, and that vapor of water and gases evolved from the earth are dissipated in the atmosphere.

This action occurs even when the bodies are separated by membranes, a film of water, or a stratum of any porous material, as unglazed earthenware, chalk, stucco, &c. But the material, in most cases, exerts a condensing action on some of the gases. If we cover a glass jar, containing carbonic acid, with an air-tight film of Indian rubber, it will be found that the Indian rubber will soon begin to lose its horizontal form and curve inwards; in a few hours it will be quite concave; but sooner or later it will begin to rise again, and after a day or two, will return to its plane figure. This experiment illustrates the passage of gases through tissues, but it also shows their condensing power, for the in-curving of the Indian rubber is due to the escape of carbonic acid into the air and its condensation; this is much more rapid than the penetration of the air from without, and the figure of the membrane expresses the difference; but, after a few days, an equilibrium is attained after as much air has passed inwards as there was gas diffused from the jar.

But, independently of the action of tissues and porous bodies, the rate of diffusion differs, being, according to Professor Graham, less as the density increases, or inversely as the square root of the density. The rise of vapors into air also takes place according to this law.

It is by the diffusion of gases that the blood becomes arterialized. Venous blood, presenting itself in the lungs to the mucous membrane of the air cells, is brought in contact with the gases of the atmosphere; and there being a considerable capillary affinity between the fluid and oxygen, and little or none for nitrogen, the former is condensed, and enters the circulating fluid, altering its characters. At the same time, the carbonic acid, suspended in the blood, diffuses off into the gas of the air cells, which contains but little before this action transpires, and, therefore, acts as a vacuum towards it. More oxygen enters than carbonic acid escapes, the difference being in the proportion of their diffusive power, or diffusion volume, or as 1000. of carbonic acid to 1175.85 of oxygen. These numbers are derived from the elaborate researches of Brunner and Valentin, and are perfectly coincident with the calculations of Professor Graham. Hence, the diffusion of gases in the function of respiration is a process purely mechanical, and altogether independent of any vital action. For the further investigation of respiration, see the section on that subject in animal chemistry.

I have shown that the passage of carbonic acid, from the air into plants, and the expiration of oxygen and nitrogen, are equally mechanical functions; such gases entering as are solicited by the composition of the plant gas, and others, passing outwards, as they are in excess, over the atmospheric mixture. Membranes are, however, barriers to diffusion, for some gases do not penetrate them under certain circumstances. Diffusion, whether from an open vessel or through porous systems, continues until the gas on both sides becomes identical in mixture, if no part of it be removed by chemical or other causes.

*Mechanical Properties of the Atmosphere.*—Air, like all the gases, is eminently elastic and compressible, and its physical properties turn upon these qualities. It has weight, as may be shown by exhausting a vessel by the air pump, weighing; and then allowing air to enter again, and re-weighing; 100 cubic inches weigh about 30.14 grains. The action of wind is a direct consequence of its weight. But we find that if 100 cubic inches be examined on the summit of a mountain of considerable elevation, it will not weigh so much, and the higher we ascend, the less its weight. Observations on this subject, prove that the diminution is not according to a simple progression, but that as the distances increase from the earth's surface, the densities diminish in a geometrical progression. Thus, at the distance of 2.704 miles, the density of the air is one half of the number at the sea level; now, at double this height, or 5.41 miles, it is only  $\frac{1}{4}$ th, at 10.82 miles  $\frac{1}{8}$ th, and at 16.23 miles  $\frac{1}{16}$ th. In these instances, if the altitudes be made to follow an arithmetical progression, the densities are in an inverse geometrical order. This arises from the condensi-

bility of air, for those parts near the earth being pressed upon by the bulk above, are condensed, become heavier, and exert more pressure.

The *barometer* is a simple and useful instrument, for the measurement of the weight or pressure of the air under different circumstances. If we select a glass tube, of about 33 inches in length, seal one end hermetically, fill it with pure mercury, and then placing the finger over the open end, invert it into a cup of quicksilver, and remove the finger, it will be found that the fluid, after a few oscillations, comes to rest, and at the sea-level stands at 30 inches or thereabouts; this instrument, furnished with a scale graduated in inches, is a barometer. A few niceties are necessary in making a fine instrument, such as boiling the mercury in the tube, &c., which do not affect the principle of the instrument.

In this case, the mercury is sustained by the pressure of the air on the outside of the cup; it will rise no higher whatever the length of the tube, all the portion above the fluid being a vacuum, and called the *Torricellian vacuum*. We can readily prove that the mercury is sustained by the pressure of the air; for, upon placing the cup under an air-pump, and removing the air, the column sinks in proportion to the rarefaction. If we ascend mountains with the barometer, the mercury falls, representing accurately the density of the air, and it has been employed for the admeasurement of altitudes.

The actual pressure of the air is readily ascertained by weighing the mercury in a tube of a given section; thus, if the tube be one square inch in bore, the mercury weighs 14.9 lbs., or as is more commonly said, 15 lbs., on the square inch. This represents the weight and pressure of a column of air from the earth's surface to the limit of the atmosphere, and is called *a pressure of one atmosphere* in mechanics, and when speaking of the condensation of gases. That the pressure does not exceed this amount, may be proved by ascertaining the weight of other columns of fluid of the same section, as water; it will be found that about 30 feet of water are sustained by the atmospheric pressure, which weigh but 14.9 lbs. No vacuum, however perfect in a pump, can draw water higher than this, because the pressure of the atmosphere fails.

The barometer not only indicates the elevation of any place above the level of the sea, but also the variation in pressure to which the atmosphere of any place is subject. The action of wind and heat in producing upward currents, the different specific gravity of moist and dry air, are so many causes of change perpetually operating on this instrument. By variations, originating in these and similar causes, it is subject at the sea level to fluctuations between 31 inches and 27 inches, and, as a general rule,

the dryer and calmer the air, the higher it rises, and the moister and more windy, the lower it falls. Hence it is called a weather-glass, because when low it often indicates rain, and when high, fine, dry weather. Indeed, taken with the dew-point, it furnishes measures of great value to the meteorologist.

Like all other gases, air follows the rule of condensation termed Marriotte's law, and already given. The atmosphere is also colder as we ascend, in consequence of its non-conducting power and its distance from the earth; on this subject we have already treated in the chapter on heat. Like all gases, it offers little impediment to the passage of light and heat through its parts. Being under considerable pressure at the earth's surface, it penetrates the pores of solids and fluids, and may be drawn from them by removing the pressure, as under the air-pump. A number of familiar experiments are devised to prove its weight, pressure, elasticity, condensibility, &c., which it is unnecessary to describe in this place.

The color of the air is due to the absorption of some of the rays of light in their passage; the red and yellow are chiefly affected, the blue being transmitted almost without loss. The golden hues of sunset are produced on the other hand, by the absorption of the blue by vapor of water. Heat is also slightly absorbed by great thicknesses of air.

*Importance of the Atmosphere.*—We have nothing to say on its mechanical importance, but only on its relations to animals and plants. The laws regulating its temperature and degree of moisture, and the formation of clouds, have been adduced in the chapter on heat. Without its presence, animal and vegetable life would be impossible; indeed, the connection between the constitution of the air and the forms of existence is complete; the atmosphere in remote ages being materially different from its composition now, the plants and animals have also differed. It has been called a reservoir for everything that is gaseous or vaporous on the earth, and geology reveals a period when nearly, if not all the water and carbonic acid gas now condensed, were in the atmosphere. At those periods, existence would be impossible, and the gradual appearance of successive races on the earth is more intimately connected with the subsidence of gases and vapors than with any other cause except heat. The epoch when gigantic plants flourished, to the exclusion of land animals, was necessarily associated with a large amount of carbonic acid in the atmosphere, which is one of the chief aliments of vegetables and deleterious to animals.

As respects the gases of the air, plants possess a function entirely different from animals; they absorb its carbonic acid and ammonia, and exhale oxygen and nitrogen; whilst animals in-



spire oxygen and exhale carbonic acid. Plants purify the air for animals, and at one time this action was supposed to be essential to the maintenance of animal life; but we now know that by diffusion, the gases are so completely mixed, that no change can affect the atmosphere except it be on a prodigious scale. It is calculated by Prof. Dumas that the whole atmosphere weighs as much as 581.000 cubes of copper, one kilometre (about 1094 yards, or  $\frac{5}{8}$ ths of a mile), on the side; its oxygen being 134.000 such cubes. On the extreme calculation, that there may be four thousand millions of animals on the earth, these will not consume more than 15 to 16 cubes of the oxygen in the year. Hence, whilst it is true that animals consume oxygen, and plants carbonic acid, there is no change in the atmosphere—these bodies being restored by expiration, and in the final decomposition to which all living things are destined. The particular changes which occur in animal and vegetable respiration will be considered in the part of this book devoted to organic chemistry.

The atmosphere is of great interest in a chemical point of view; its active agents, oxygen, carbonic acid and vapor of water, are incessantly acting on bodies. Oxygen is essential to combustion, which cannot take place without it; it also causes the rusting of iron, and acts upon animal and vegetable bodies, inducing fermentation and decomposition. It loses little of its chemical energy by union in the atmosphere. Carbonic acid acts upon the alkalies, on lime, &c., converting them into carbonates, and rendering certain precautions necessary in their analysis and preservation. The different amounts of this gas in the air are dependent upon the action of rain, and prolonged dry weather; in the latter case, it accumulates; it also rises in amount during dry, gloomy weather; but rain washes it out of the atmosphere, bringing it down to the minimum. The vapor of water is constantly acting on certain saline bodies, causing their deliquescence; it also affects the weight of gases, and bodies which have a great affinity for moisture. Its presence is highly conducive to the development of vegetation by arresting evaporation, which, if excessive, causes the destruction of plants.

#### CHEMICAL COMPOUNDS OF NITROGEN.

We propose to consider in this place the compounds of nitrogen, with oxygen and hydrogen. There are five compounds with oxygen:—

1. The protoxide of nitrogen = NO
2. The deutoxide (binoxide) of nitrogen = NO<sub>2</sub>
3. Hyponitrous acid = NO<sub>3</sub>
4. Nitrous acid = NO<sub>4</sub>
5. Nitric acid = NO<sub>5</sub>



And three compounds with hydrogen :

1. Amidogene =  $\text{NH}_2$
2. Ammonia =  $\text{NH}_3$
3. Ammonium =  $\text{NH}_4$

THE PROTOXIDE OF NITROGEN—*Nitrous Oxide*. Formula  $\text{NO}$ ; eq. 22.0.—This gas is obtained with great facility, by heating the crystallized nitrate of ammonia in a retort, and collecting the product in suitable receivers. The composition of this salt is  $\text{NH}_4\text{O} + \text{NO}_5$ , and the heat splits it into 2 ( $\text{NO}$ ), 2 atoms of protoxide of nitrogen, and 4 ( $\text{HO}$ ), 4 atoms of water, producing a new grouping.

*Characters*.—It is colorless, without odor, and of a sweetish taste, sp. gr. 1.527. Water dissolves about three-fourths of its own volume when cold, and but little, when heated above  $90^\circ \text{F}$ . It may be liquefied, and even rendered solid by cold and great pressure.

*Properties*.—It is not inflammable, but is a good supporter of combustion. It does not possess chemical activity, excepting so far as the separation of its oxygen is concerned, for in the combustion of bodies in this gas, decomposition ensues, and nitrogen is set free; the oxygen being the active agent. When it is inspired, the circulation is hurried, and an excited state of the brain and muscular system is produced. Hence, it has been called *the laughing or intoxicating gas*. Its physiological action is as follows: containing half its volume of oxygen gas, and being readily absorbable by moist surfaces, it passes rapidly into the blood when inspired. This fluid, rendered abnormally rich in oxygen, circulates faster, and produces changes in the system much more rapidly than usual, hence increase of heat, greater muscular and mental activity—for all these functions are dependent on the action of oxygen in arterial blood.

*Therapeutic Uses*.—It is not for amusement only that this gas may be employed; it is an agent of great value in restoring life in cases of asphyxia, arising from narcotism, ether, drowning, carbonic acid gas, or any other cause. For this purpose, air mixed with one-half protoxide of nitrogen may be thrown into the lungs by artificial respiration, and if the blood have not entirely lost its fluidity the current will be re-established. It is superior to oxygen for this purpose, from its ready solubility. We have great faith in the employment of this agent with the galvanic battery in cases of drowning.

A solution of protoxide, under pressure, similar to the carbonated water, appears to us to promise good effects in cases of dyspepsia, and want of tone in the chylopoietic viscera. It

would furnish an agreeable and healthy stimulus, and be altogether superior in its action to oxygenated water, which has been recommended in similar cases.

DEUTOXIDE OF NITROGEN—*Binoxide of Nitrogen*—*Nitric Oxide*.  $\text{NO}_2$ ; eq. 30.0.—A gas procured by pouring nitric acid on copper, and collecting the product over water in a receiver.

*Characters*.—Colorless, inodorous, sp. gr. 1.04. Water dissolves five per cent. of its volume.

*Properties*.—It neither supports combustion, nor is inflammable, but heated phosphorus continues to burn in it by decomposing the mixture. Iron and other bodies separate half its oxygen to become oxydized. When it is introduced into a gaseous mixture containing oxygen, as the air, it produces red fumes of nitrous acid, and has been therefore used in the analysis of such mixtures. For this purpose, an equal volume of deutoxide is added over water in a slow stream, the resulting nitrous acid is soon absorbed, and one-fourth of the deficit represents the oxygen of the mixture. It is irrespirable.

HYPONITROUS ACID—*Nitrous acid* (*Graham*).  $\text{NO}_3$ ; eq. 38.0.—This is an instable, yellowish, acid and volatile fluid in the cold, and not directly employed. It combines both with acids and bases, and is associated by Graham with arsenious acid and the oxide of antimony.

NITROUS ACID—*Peroxide of Nitrogen* (*Graham*).  $\text{NO}_4$ ; eq. 46.0.—If dry nitrate of lead,  $\text{PbO} + \text{NO}_5$ , be distilled in an earthenware retort at a red heat, and the distillate received in a vessel cooled by ice, a colorless liquid is obtained, which is the nitrous acid. The salt is resolved not into nitric acid and oxide of lead, but into  $(\text{PbO})$  oxide of lead,  $(\text{NO}_4)$  nitrous acid, and one atom of oxygen, which passes off as a gas. This decomposition is of considerable interest in showing that nitric acid has no existence without the presence of water.

*Characters*.—The liquid acid is nearly colorless at zero; but when heated, becomes of an orange color, and evolves fumes which become nearly black, as the temperature rises. It solidifies at  $40^\circ$  and boils at  $82^\circ$  F. Specific gr. 1.451.

*Properties*.—It is not decomposed at a red heat, but becomes changed by contact with water into nitric acid, and deutoxide of nitrogen. But strong nitric acid dissolves a small quantity. It becomes gaseous, when mixed with air, is of a suffocating odor, and unpleasant smell. Its salts, which are unimportant, and made by indirect processes, are termed *nitrites*.

NITRIC ACID—*Azotic Acid*. Symbol  $\text{NO}_5$ ; eq. 54.0.—The compound  $\text{NO}_5$  does not exist in the separate state, but is known with one equivalent of water  $\text{HO} + \text{NO}_5$ , and in numerous compounds.

The strong acid of commerce is obtained by distilling a mixture of equal weights of nitrate of potash or soda, and strong sulphuric acid over a small furnace, and receiving the product in a refrigerated receiver. In this way a slightly colored fluid, consisting of  $\text{HO} + \text{NO}_5$ , is obtained, which is the strongest nitric acid. The action is as follows: the sulphuric acid ( $\text{HO} + \text{SO}_3$ ) combines with the potash of the nitre ( $\text{KO} + \text{NO}_5$ ), forming bisulphate of potash ( $\text{KO} + 2\text{SO}_3$ ), and there remain  $\text{NO}_5$ , and one atom of water ( $\text{HO}$ ) formerly in union with the sulphuric acid, these unite, forming  $\text{HO} + \text{NO}_5$ , and being volatile, pass over, and are condensed in the receiver.

*Characters.*—It is a nearly colorless and intensely caustic fluid, throwing off a disagreeable vapor at all temperatures. By exposure to light, it becomes yellow, and even orange in color. When pure, it boils at  $187^\circ$ , and freezes at  $40^\circ \text{F.}$ , and has a specific gr. of 1.521. The strength of a specimen may be determined by its sp. gr., for this becomes less as it is diluted with water.

*Properties.*—It is an acid, by which is meant, that it combines with bases or metallic oxides, reddens blue litmus paper, is sour, and neutralizes alkalies. These are the general properties of acids, although some are not sour. It is one of the most powerful solvents, destroying most metals, and converting them into oxides; the acid subsequently uniting with the oxide produced by the first action. Hence, it is readily decomposed, yielding its oxygen to most active bodies, and assisting combustion. It may be destroyed by being passed through a red hot tube, being changed into nitrous acid and oxygen. Light effects the same change slowly. In consequence of the facility with which it gives off oxygen, it is a valuable oxydizing agent. It has a powerful affinity for water, uniting with it in various proportions.

The chemical nature of nitric acid is a subject of much interest. It has already been remarked that the anhydrous compound  $\text{NO}_5$  has no existence, and the strongest acid contains one atom of water; but, according to the most modern views, the water does not unite as such, but seems to change the nature of the compound, and instead of forming  $\text{HO} + \text{NO}_5$ , produces  $\text{H} + \text{NO}_6$ , in which  $\text{NO}_6$  is the acid, and  $\text{H}$  (hydrogen) represents a metallic radical. The salts of this body, nitrates, have an analogous constitution, and may be represented by  $\text{M} + \text{NO}_6$ , in which  $\text{M}$  is a metal. If a metallic oxide unite with  $\text{H} + \text{NO}_6$ , there is produced a nitrate, and an atom of water ( $\text{HO}$ ) formed by the union of the oxygen of the oxide with the  $\text{H}$  (hydrogen), which is substituted by the metal. Examining, also, the case of sulphuric acid,  $\text{H} + \text{SO}_4$ , and other acids, it would appear that the presence of hydrogen, and its ability of being replaced by a

metal, constitute the acid structure; and that acid properties are not the effect of the presence of several atoms of oxygen, but arise from the fact that the hydrogen may be substituted by most other metals.

This constitutes *the hydrogen theory of acids*, and it serves to assimilate most of these bodies, for  $H+Cl$ ,  $H+I$ ,  $H+Br$  are brought into this list, from which they are otherwise excluded, although they have the action of powerful acids. But it is not to be disguised that there are objections to this view.

*Tests.*—Nitric acid stains animal, and most dry vegetable tissues, yellow, and is hence used in dyeing. It may be known by its action on the salts of morphia, when in the free state, as it produces with them a deep orange color. The nitrates are not soluble, and cannot, therefore, be precipitated, but they deslagrate on a hot coal. In the concentrated state, or as *aqua fortis* of the shops, in which it contains two or more atoms of water, it is known by producing red fumes when poured on strips of copper. A little, boiled with a solution of indigo, bleaches it.

*Uses.*—In the arts, it is employed to dissolve metals, in etching, and for the purpose of preparing many chemical bodies. In medicine, it may be used as a caustic, and in the diluted state is employed as a tonic and refrigerant.

It is sometimes taken internally by accident, and proves a powerful corrosive poison. In such cases, and the remarks apply also to the sulphuric, muriatic and oxalic acids, the best antidote will be calcined magnesia, made into a cream with water. If this cannot be had, chalk, carbonate of magnesia, pearlash, or carbonate of soda will do, but are inferior, from the large amount of gas extricated in their union with the acid. If magnesia be used, it will neutralize the acid, being converted into the nitrate, which is not poisonous. But in these cases the acids act so violently if strong, that little hope can be entertained of recovery. Sometimes they are sprinkled on the hands or face of persons with malicious intentions, and produce ulcers difficult of cure. The dressing to these, should at first contain magnesia, to neutralize any free acid.

*Salts.*—The most important salts are the nitrates of potash, soda, ammonia, iron, lead, bismuth, copper and silver.

COMPOUNDS OF NITROGEN WITH HYDROGEN.—Of the three compounds enumerated, one only is known in the free state, ammonia,  $NH_3$ ; hence, until recently, this was supposed to be the only product of their union, and great confusion has arisen in the nomenclature of these bodies, especially with acids and haloid bodies. Thus, muriate of ammonia is now chloride of ammonium—sulphate of ammonia, sulphate of the oxide of ammonium.



*Amidogene*— $\text{NH}_3$ ; symbol Ad=16.0.—It is inferred to exist in a class of compounds called amidides, one of which, the amidide of potassium, is produced when dry ammonia ( $\text{NH}_3$ ) is heated with potassium, an atom of hydrogen is separated, and  $\text{K} + \text{NH}_2$  results. It combines also with mercury and other metals, which in every case replace an atom of hydrogen, hence it is an electro-negative compound radical like cyanogen, and ammonia is an amidide of hydrogen.

AMMONIA—*Amidide of Hydrogen*. AdH— $\text{NH}_3$ ; eq. 17.0.—Pure ammonia is a highly pungent gas, but it is generally known in solution in water. Its compounds, especially the carbonate and sulphuret, are obtained by the distillation of bones and other animal substances. In the decay of all animal, and many vegetable matters, it is evolved, and hence there is a minute amount in rain water and the atmosphere.

It is procured in large quantities for commercial purposes, by heating sal ammoniac (chloride of ammonium) with slaked lime, and conducting the ammoniacal gas into receivers nearly filled with water. The solution constitutes the *aqua ammonia* or water of ammonia of the shops. For experiment, the gas can be had by heating the solution, and collecting over mercury, or into a vessel inverted over the tube of the generating bottle.

*Characters*.—Ammoniacal gas is colorless, has a pungent odor and alkaline taste. Its sp. gr. is 0.59; water at  $32^\circ \text{F}$ . dissolves 780 times its bulk, and acquires the properties of the gas. By a pressure of  $6\frac{1}{2}$  atmospheres, or a cold of  $-61$ , the gas is liquefied. The most concentrated solution of ammonia contains  $32\frac{1}{2}$  per cent. of this body, has a sp. gr. of 0.872, and boils at  $120^\circ \text{F}$ . The strength may be determined by the density, which rises with the feebleness of the solution.

*Properties*.—The gas is slightly combustible, a non-supporter of combustion, entirely irrespirable and poisonous. The solution, *volatile alkali*, is caustic, volatile and alkaline, by which is meant that it neutralizes acids, turns reddened litmus paper blue, or converts turmeric paper brown, and acts in all respects like potash and soda, which are alkalies. Formerly a large number of compounds were supposed to contain this body, and called salts of ammonia, as the carbonate (*sal volatile*), muriate (sal ammoniac), sulphate, &c., which are now known to be compounds of ammonium. But ammonia does combine with some substances, and forms compounds, to which Prof. Kane has given the name of *ammonurets*. The ammonurets contain usually a metallic oxide, are of very instable constitution, and often violently explosive, as the fulminating compounds of silver, gold and mercury. It is also present as a neutral body, in the same way as the water of crystallization of many salts, especially the sulphate of copper



and ammonia. Ammoniacal gas is readily decomposed by electricity, or by being sent through a red hot iron tube, being resolved into one atom of nitrogen and three of hydrogen.

*Tests.*—The presence of free ammonia is determined by its pungent odor; by bringing a rod moistened with muriatic acid near it, when dense white vapors are produced; or by adding it to a feeble solution of sulphate of copper, which is instantaneously changed into a deep purple blue.

*Uses.*—It is used for the manufacture of many medicines, in tests, and in perfumery and medicine. The *aqua ammoniæ* is antacid and valuable stimulant in a diluted state; the carbonate is, however, preferred. The vapor is restorative, but inhaled too freely, produces great irritation of the nerves, and may cause death if inspired into the lungs; indeed, its use as a restorative in fainting is improper.

The solution is somewhat caustic, and may cause death if taken in over doses. It is violently stimulating, and has to be met by an acid, of which dilute vinegar is the best, being always at hand, and serving to neutralize the alkali completely. Demulcents should be employed at the same time to counteract the irritation of the poison on the coats of the stomach. The course pointed out in this case, is equally applicable to poisoning by soda, potash, or the carbonates of potash or ammonia.

AMMONIUM— $\text{NH}_4$ ; eq. 18.0. Symbol Am.—This body has not been insulated, but exists combined with mercury in the ammoniacal amalgam and other substances. The amalgam is made by adding a small portion of sodium to mercury, and bringing it in contact with solution of ammonia—the mercury swells considerably, becomes of the consistence of butter, and is supposed to become united with ammonium. If we attempt to separate it from the amalgam, there results  $\text{NH}_3$ , and H (hydrogen).

Ammonium is an electro-positive compound radical resembling the metals, and especially potassium and sodium. It forms a series of compounds with the haloid bodies, as  $\text{AmI}$ ;  $\text{AmCl}$ ;  $\text{AmBr}$ ; the iodide, chloride and bromide of ammonium, which correspond to analogous salts of potassium and sodium. The chloride of ammonium is the saline substance, well known under the name of muriate of ammonia or sal ammoniac, and used in lotions as a discutient and in refrigerating mixtures.

The *oxide of ammonium*,  $\text{NH}_4\text{O}$ , or  $\text{AmO}$ .—This is hypothetical, but in its compound with acids produces salts, isomorphous with those of the oxides of potassium (potash) and sodium (soda). The common salts, called compounds of ammonia, contain this oxydized radical, as the sulphate,  $\text{AmO} + \text{SO}_3$ —the nitrate,  $\text{AmO} + \text{NO}_5$ , or  $\text{NH}_4\text{O} + \text{NO}_5$ .

The principal salts of ammonium belong to organic chemistry,

for these bodies are derived, for the most part, from decaying animal and vegetable matters.

## SULPHUR.

*Symbol, S. Equivalent, 16.1.*

SULPHUR is found native in volcanic regions, and is combined with many metals in ores, as an electro-negative body. The native crystals are right rhombic octahedrons and translucent, but those made by melting are oblique rhombic prisms, and it is therefore dimorphous. It is also a component of animals and plants.

*Characters.*—The roll sulphur or brimstone consists of melted sulphur poured into moulds; the flowers of sulphur are minute crystals obtained by subliming. There is a third variety called precipitated or milk of sulphur, obtained by adding muriatic acid to a solution of sulphuret of lime, which is almost white, and preferred in medicine under the name of *sulphur præcipitatum* or *lac sulphuris*.

Solid sulphur is tasteless, crackles when heated, exhales a characteristic odor when warmed, is insoluble in water, and has the sp. gr. of 1.98. It melts at 226° into an amber fluid, but if the heat be raised to 450, it becomes dark, thick and tough, but afterwards becomes thin and limpid, and boils at 600° F., throwing off an abundant vapor which sublimes into the flowers of sulphur in an air-tight vessel. It is little soluble except in oily and alkaline fluids.

*Properties.*—Sulphur is a powerfully electro-negative element, combining with most metals when nascent, or when heated with them, and forming *sulphides* or sulphurets. It is eminently combustible, taking fire at 300° F. in the air; it is also a supporter of combustion, iron burning brilliantly when introduced at a red heat into its vapor.

It is an excellent electric, becoming electro-negative by friction, and, as in most similar cases, it is a bad conductor of heat.

In its chemical relations, sulphur resembles oxygen, and may be placed in the same isomorphous class. Its chief use in medicine is as a topical application to scabies, and diseases of the skin, and as a laxative for children.

*Compounds.*—With oxygen it forms six compounds, of which only two are of medical interest. They are as follows:—

Sulphurous acid= $\text{SO}_2$	Sulphuretted hyposulphuric acid= $\text{S}_3\text{O}_5$ Bi-sulphuretted hyposulphuric acid= $\text{S}_4\text{O}_5$
Sulphuric acid= $\text{SO}_3$	
Hyposulphurous acid= $\text{S}_2\text{O}_2$	
Hyposulphuric acid= $\text{S}_2\text{O}_5$	

With hydrogen it forms sulphuretted hydrogen, or sulphide of hydrogen,  $\text{HS}$ —and  $\text{HS}_2$ , or deuto-sulphide of hydrogen.

**SULPHUROUS ACID**— $\text{SO}_2$ ; eq. 32.1.—This is a pungent gas produced by burning sulphur in oxygen gas. It may also be obtained by heating sulphuric acid with mercury.

*Characters.*—It is colorless, has an offensive odor, sp. gr. 2.222, very soluble in water, and converted by the cold of zero into a limpid fluid, which boils at  $14^\circ \text{F}$ .

*Properties.*—It is irrespirable, a non-supporter of combustion, not inflammable, and highly poisonous, especially to insects. The moist gas possesses considerable bleaching powers, especially towards yellow colors, but is not as perfect in its action as chlorine, for the colors can be restored by stronger acids. It is a feeble acid, and forms salts with the alkaline bases called *sulphites*; which are of little importance, but are sometimes employed as deoxydizing agents in the laboratory to separate the oxygen from metallic compounds.

Sulphurous acid is an ingredient in the sulphur and some medicated vapor baths. In this state, it excites the skin, and appears to be serviceable in diseases in which there is want of action in the skin. Such baths are particularly recommended in rheumatism, but this is more probably due to their temperature than the presence of sulphurous acids.

**SULPHURIC ACID**—*Oil of Vitriol*— $\text{SO}_3$  or  $\text{H} + \text{SO}_4$ ; eq. 40.1.—The sulphuric acid of commerce is obtained in immense quantities by burning nitrate of potash or soda and sulphur in contact with air, and conveying the vapors into chambers lined with lead, and containing water. The product, which is weak sulphuric acid, is then concentrated by boiling in platinum vessels. The changes occurring in the process are complicated, and in some dispute.

*Characters.*—Strong sulphuric acid is an oily, colorless fluid, powerfully acid and corrosive; sp. gr. 1.845. It freezes at  $-15^\circ$ , and boils at  $620^\circ \text{F}$ .

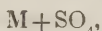
*Properties.*—It is a powerful acid, and possesses an intense affinity for water, charring most vegetable and animal bodies by separating it from their texture. It combines with nearly all metallic oxides to form *sulphates*; and in some cases, it acts as an oxydizing agent, as when heated with mercury; a portion of the acid losing an atom of oxygen to form oxide of mercury, and other portions uniting with this base. In such cases, sulphurous acid  $\text{SO}_2$ , is evolved. The acid distills over at a temperature of  $620^\circ$ , and is driven off from most of its compounds by a red heat.

There were three bodies confounded until recently under this name:—1st, anhydrous sulphuric acid, or  $\text{SO}_3$ ; 2d, fuming acid of Nordhausen; 3d, hydrated sulphuric acid.

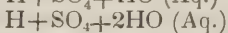
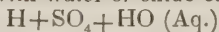
*Anhydrous* sulphuric acid is a white, silky, crystalline body, which fumes in the air, melts at  $77^{\circ}$ , and becomes a vapor at  $160^{\circ}$  F. It has an intense affinity for water, but can scarcely be said to possess acid properties, except when combined with water. It consists of one atom of sulphur with three of oxygen  $=\text{SO}_3$ . It is of no known use.

*Acid of Nordhausen.*—This is the true oil of vitriol, and is procured by the distillation of dry sulphate of iron at a red heat. It is of a brown color, fuming, sp. gr. 1.9; when heated, dense vapors of anhydrous acid pass over, and there remains common sulphuric acid. It is, therefore, a compound of  $\text{SO}_3$ , with  $\text{HO}, \text{SO}_3$ . It is chiefly used for dissolving indigo.

*Hydrated Sulphuric Acid.*—In its purest state, this consists of  $\text{HO}, \text{SO}_3$ ; and, according to the views of those who advocate the hydrogen theory of acids, is  $\text{H}, \text{SO}_4$ , in which H may be substituted by any metal. To form the sulphates, all that is necessary is to bring a metallic oxide in contact with this body; the hydrogen unites with the oxygen of the base, and there is produced the compound



which represents the general formula for the protosulphates, in which M may be an elementary metal, or an electro-positive compound radical, as ammonium. Among the compounds of sulphuric acid, are two with water or oxide of hydrogen:



The office of the water here is not ascertained, but it appears to be water of crystallization. It is in the formation of these bodies that so much heat is given out when the strong acid  $\text{H} + \text{SO}_4$  is combined with water.

*Tests.*—Sulphuric acid or a soluble sulphate is readily recognized by the action of a solution of chloride of barium, which throws down a dense white precipitate insoluble in nitric acid. It may also be known by its causticity, oily appearance, its action in reddening black and most colored cloths, and the dense vapors it produces at a high temperature.

*Salts.*—The number of sulphates is immense, but in medicine, the following only are of moment. Sulphate of potash, soda, lime, oxide of ammonium (sulphate of ammonia), iron, copper, zinc, mercury, alumina and potash (alum), magnesia, quinine, morphine, strychnine, &c.

*Uses.*—In the arts and manufactures, it is of great value, chiefly for the preparation of chemicals and dyes. In medicine, the strong acid is a caustic, a dilute acid is employed in ointment as a stimulating application to chronic ulcers and cutaneous diseases; it is also a good styptic. A weak acid, made by adding one



ounce of the strong acid to 13 of water, is employed internally in doses of 10 to 30 drops in water as a refrigerant, tonic and anti-hemorrhagic. But if long-continued, it produces a form of chronic gastritis.

*Poisoning.*—It is a violent poison, destroying the parts over which it passes at once when strong, and producing intense inflammation, when dilute; it also prostrates the system, and reduces the action of the heart. In doses which are not speedily fatal, it sometimes produces a chronic inflammation that causes death in a few weeks. The acid disorganizes by uniting with the water of the tissue, and also by forming a solid with its albumen. The antidote is magnesia, as stated in the article on nitric acid.

In cases of death by poisoning, the presence of the acid may be ascertained by washing the parts, filtering and concentrating the solution; or if some time have elapsed, scraping off the disorganized tissues, distilling with a little water, and testing the distillate with chloride of barytes and by other means, will be necessary. Care must be taken not to confound the precipitate with those procured from soluble sulphates, as Epsom salt, alum, &c., which may have been used as medicines. For this purpose, distillation is best, as the salts will be left in the retort.

**HYPOSULPHUROUS ACID**— $S_2O_2$  or  $H+SO_3.S$ .—It has not been insulated, but its salts, the hyposulphites, are known, and one, the *hyposulphite of soda* is used in the Daguerreotype to dissolve the iodide, bromide, &c. of silver. This is formed by digesting a strong solution of sulphite of soda on flowers of sulphur at a good heat, but without boiling.

**HYPOSULPHURIC ACID**— $S_2O_5$  or  $H+SO_3+SO_3$ .—This is a thick fluid of intense acidity, and readily decomposable by heat into sulphuric and sulphurous acids.

*Note.*—These two acids have all the appearance of compounds of sulphurous acid  $H+SO_3$ , and there are in addition several bodies of a similar structure, which are tabulated in the following. They are not of importance in medicine or the arts.

Sulphuretted hyposulphuric acid (*Langlois*),  $H+2(SO_3)+S$

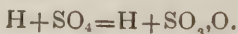
Bi-sulphuretted hyposulphuric acid (*Fordos and Gelis*),  $H+2(SO_3)+S_2$

Chloro-sulphuric acid,  $H+SO_3+Cl$

Nitro-sulphuric acid,  $H+SO_3+NO_2$

Iodo-sulphuric acid,  $H+SO_3+I$ .

From the above, and analogous compounds, sulphurous acid,  $H+SO_3$ , is regarded a compound radical. It is the most stable of the sulphur oxides, since sulphuric acid may be resolved into it; therefore, all these acids, and many other compounds may be set down as compounds of this body, and as, in the case of sulphuric acid, written





## SULPHUR WITH HYDROGEN.

**SULPHIDE OF HYDROGEN.**—*Sulphuretted hydrogen*—*Hydro-sulphuric Acid*—*Sulphydric Acid*— $\text{HS}$ ; eq. 17.1.—A gas existing in minute quantities in stagnant waters, and some springs, and evolved by putrid matters. It is readily obtained for examination and chemical use by pouring dilute sulphuric acid on sulphide of iron. In this case  $\text{H} + \text{SO}_4$ , Aq., and  $\text{FeS}$  becomes changed into  $\text{Fe} + \text{SO}_4$ , Aq. and  $\text{HS}$ , or sulphide of hydrogen. The  $\text{Fe} + \text{SO}_4$  is common sulphate of iron or green vitriol.

*Characters.*—A fetid gas, having the odor of rotten eggs, colorless, with a disagreeable taste; sp. gr. 1.177. Cold water dissolves its own bulk. The gas is rendered fluid by a pressure of 17 atmospheres at  $50^\circ \text{F}$ .

*Properties.*—The gas is inflammable, and burns in the open air into water and sulphurous acid. It is violently poisonous, and this arises from its solubility in the fluids of the body, as well as its power of disorganizing the blood. The antidote is chlorine gas, diluted with air, and inhaled.

It is one of the most active bodies in chemistry, acting upon nearly all the metals and their soluble oxides to produce sulphides. In these cases it is decomposed, the metals taking the place of the hydrogen and forming the compound



in which  $\text{M}$  is a metal, or an electro-positive compound radical. When a metallic oxide is present, the  $\text{H}$  unites with the oxygen to form water ( $\text{HO}$ ). Hence it is much used as a test in chemical manipulations, to separate the metals from their compounds, as most of the sulphides are insoluble. For this purpose a stream of gas is passed through the solution, or sulphide of ammonium is employed. The former is one of the tests for arsenious acid, which it throws down of a yellow color.

Aqueous sulphide of hydrogen is slightly acid, but this body most nearly resembles water in its chemical habitudes. This compound is readily decomposed by heat or by metallic bodies.

*Tests.*—It is known by its odor, and by blackening silver, and test paper prepared with the acetate of lead.

*Uses.*—It is one of the most valuable tests in the laboratory, for the detection and separation of the metals. It is also much used as a medicine in the various sulphur springs of Virginia, Kentucky, and other states. In these the amount of gas is seldom more than 20 cubic inches in 100 of water, but the liquid is remarkably disagreeable, and fetid. These waters are chiefly employed by persons suffering from chronic dyspepsias, hepatic diseases and affections of the skin. They are stimulating, and

being frequently conjoined with the alkaline sulphates, are also purgative. Hot baths of them are highly favorable in rheumatism and old cutaneous affections. Artificial sulphur waters are rarely used.

*Poisoning.*—The gas evolved in chemical processes and from cesspools, may produce death when inhaled. It acts as a nervous sedative, producing giddiness, nausea, prostrating the system, stopping the heart's action, and inducing asphyxia; if this effect is not reached, there is produced a bilious diarrhœa, with great debility. The patient is to be freely exposed to fresh air, a diluted gaseous mixture of chlorine may be thrown into his lungs, or the chloride of lime, on which a few drops of dilute acid have been placed, may be applied to the nose. The after treatment is to be directed to the restoration of the tone of the nervous and circulatory apparatus. The poisonous action is due to the decomposition of the blood, which is found after death blackish and fluid. The body is also highly offensive, is said to decay rapidly, and the muscles are insensible to the stimulus of galvanism.

*Malaria.*—The Italian writers have for some time suspected a connection between the presence of sulphur, and the poisonous atmosphere (*mal aria*), which produces bilious remittent and intermittent fevers. The late Professor Daniell found sulphuretted hydrogen in the waters taken from the most sickly portions of the African coast, and Dr. Marcet in those from the Chinese coast, which is equally unhealthy. I have succeeded in detecting the presence of this body, both in the air and waters of marshes and shallow streams in Virginia, and in locations where bilious remittent fever was active. (See *The American Journal of the Medical Sciences*, January, 1842.)

I do not, however, agree with Prof. Daniell and others, that sulphuretted hydrogen is the malarious body, but believe that sulphur is a component of a certain instable organic body, which constitutes the poison. This organic body may be obtained by precipitating the vapor from a marsh, in the morning before sunrise, and it blackens sulphuric acid. It consists of sulphur, carbon, hydrogen, and probably oxygen. It readily decomposes, emitting a putrid odor, and appears to be decomposed by the rays of the sun. It is destroyed by fire, does not rise high in the air, is decomposed by plants, which appear to remove its water, an essential ingredient of the body.

This substance entering the lungs, is probably decomposed into sulphuretted hydrogen, carbonic acid and water. Hence the sulphuretted hydrogen is most probably the noxious body; this enters the circulation, affects the blood, produces nervous symptoms, which have the intermittent or remittent type, affects the liver, and, if taken in large quantity, produces nervous and vascular prostration with all the symptoms of yellow fever. These would be

the effects of sulphuretted hydrogen. The best remedies, calomel, and in chronic cases nitro-muriatic acid, both contain chlorine. The first of these is decomposed in the body, and they both evolve chlorine, which, as we have seen, neutralizes the poisonous properties of sulphuretted hydrogen.

It is supposed by some that moisture is enough to produce these diseases; but why do not sailors suffer from this cause? Moreover, whilst moisture is essential to the production of malaria, a small amount will answer; it is not on marshes and water only, that the poison is found, but over new lands recently exposed to the air. In all these places there are *decaying vegetable matter and saline matters*, of which the sulphates, especially the sulphate of lime and magnesia, are the essential bodies. During the decay of vegetation in a moist situation, sulphates are decomposed and *sulphur rendered free*; it may combine with hydrogen, with other bodies to form an organic body, as we suggest, or it may unite with metallic substances, and never rise above the earth. On the coast, especially where the sea occasionally comes in contact with the vegetation of fresh water marshes, the most deadly malaria exists. Now the sea contains a large amount of sulphates. Marshes do not necessarily give rise to intermittents or remittents; the bogs of Ireland are free from these diseases. *Hence vegetable matter, in a state of decay, with an abundance of moisture, does not necessarily produce either malaria or sulphuretted hydrogen.*

We may go further, and state that there is no place in which violent malaria is found, that does not present us with the conditions necessary for the formation of a sulphuretted organic body, or in the waters of which sulphates may not be detected. The form of the disease depends upon the amount of poison produced in the autumn or spring, and the temperature. Nor do we deny that other causes influence the form of the disease, or that any of the malarious fevers may arise sporadically.

**BISULPHIDE OF HYDROGEN—*Persulphuret of Hydrogen*— $H+S_2$ .**—This is an oily fluid, almost spontaneously decomposable into sulphur and sulphuretted hydrogen. It is the analogue of peroxide of hydrogen, being decomposed by the same means, or catalytically, and also possessing bleaching properties.

#### SELENIUM AND TELLURIUM.

These are rare bodies, isomorphous, and closely resembling sulphur. They are of no known use. Tellurium is placed by most authors with the metals, but is scarcely known.

## THE HALOID GROUP.

## CHLORINE—IODINE—BROMINE—FLUORINE.

Fig. 51.



**CHLORINE.**—Symbol Cl; eq. 35.47.—A gas, scarcely existing in the free state in nature, but found in salt, and other compounds of the ocean. This group of elements, except fluorine, belongs to the sea, being rare in other situations.

Chlorine is obtained for examination, by pouring a solution of chloride of hydrogen (muriatic acid), on the peroxide of manganese ( $\text{MnO}_2$ ). Reaction occurs which is assisted by heat; the hydrogen of one atom of acid ( $\text{H} + \text{Cl}$ ) is released and unites with one atom of the oxygen of the peroxide to form water ( $\text{HO}$ ); its chlorine uniting with the manganese to form chloride of manganese  $\text{Mn} + \text{Cl}$ ; the second atom of the oxygen now acts upon a new equivalent of chloride of hydrogen, appropriating its hydrogen to form another atom of water, the free chlorine rises as a gas. It is collected by displacement by an arrangement like that of the figure. The fol-

lowing diagram displays these changes.

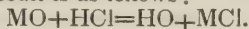
Chloride of hydrogen	{ Chlorine	—————	Free Chlorine
	{ Hydrogen	—————	Water
Deutoxide of manganese	{ Oxygen	—————	
	{ Manganese	—————	Chloride of Manganese
Chloride of hydrogen	{ Oxygen	—————	
	{ Chlorine	—————	
	{ Hydrogen	—————	Water

**Characters.**—A light green gas, of a suffocating odor and acrid taste, of sp. gr. 2.47. Water dissolves about twice its volume at  $60^\circ \text{F.}$ , acquiring its odor and some of its properties. It may be liquefied by a pressure of four atmospheres, and forms a yellowish limpid fluid.

**Properties.**—It is violently acrid and poisonous, a supporter of combustion in the case of many metals, as antimony, arsenic, &c., which take fire in it and become *chlorides*. It is not inflammable. The common gas is one of the most active electro-negative agents known, forming binary compounds, called haloid salts, with most metals of which table salt, chloride of sodium ( $\text{NaCl}$ ) is an instance. When exposed to light, it becomes more active, acquiring the alpha state; it then combines with hydrogen even ex-



sively, and forms (HCl) hydrochloric acid, one of the most active mineral acids. With this body all the metallic chlorides can be formed, by bringing their oxides in contact with it, the hydrogen forming with the oxygen, water, and the chlorine and metal uniting. The general result is as follows :



The range of its affinity is nearly equal to that of oxygen, which element it often displaces, even decomposing water when exposed to the sun's light, and evolving the oxygen. It also possesses the singular property of acting as a substitute for hydrogen in many organic bodies.—(See *Mechanical and Chemical Types*.)

Chlorine has considerable affinity for water, forming a definite compound with ten atoms, which crystallizes in yellow plates at 32° F. In union with water it is the most perfect bleaching agent known, discharging all vegetable colors and disorganizing their principles. For this purpose it is employed in its compound with lime, called the chloride of lime, from which the element is separated by exposure to the air, or by the action of acids.

It is also a disinfectant and antiseptic of the highest value. This property depends upon its affinity for hydrogen, especially in the sunlight. Hydrogen, in its combination with sulphur, is the principal ingredient in offensive animal odors, and is separated by the action of chlorine; hence the disagreeable compound is destroyed or disinfected. In the sick room a solution of chloride of soda, or of the compound called chloride of lime, may be employed to remove offensive odors. Weak solutions are also used as stimulating and disinfectant washes to foul ulcers, gangrenous sores, and some chronic eruptions.

*Tests*.—The green color of the gas and its suffocating smell are characteristic. In solution, and in the soluble chlorides, it is readily determined by acidulating with nitric acid and adding solution of nitrate of silver, when a curdy white precipitate of chloride of silver is formed, which blackens on exposure to light.

*Uses*.—Free chlorine, slowly evolved from a solution of chloride of lime or soda, is employed as a bleaching agent, and to disinfect sick-rooms and foul places; it is also inhaled in chronic bronchitis. When inspired, it produces a pungent impression on the air-passages, with cough, and a hoarseness which lasts several hours, and has therefore been recommended to stimulate them in the above disease. For this purpose a solution of chlorine in water, or the bleaching fluids may be employed, placed in an inhaler. In the nitro-muriatic bath and acid, it is the chlorine which is active.

The bleaching powders may occasionally produce poisoning, from the extent to which they are employed. They are caustic and irritant, producing inflammation of the stomach and parts over which they have passed. The antidote is the white of eggs,



which is coagulated by the action of chlorine, and destroys its activity. The gas can be seldom expected to poison, but where it has been inhaled to an injurious extent, free exposure to the air, and a course of treatment calculated to arrest inflammation of the air-passages, are necessary. It has been recommended as an antidote, in poisoning by sulphuretted hydrogen or hydrocyanic acid.

*Salts.*—The most important salts of chlorine are the chlorides of sodium (*common salt*), ammonium (*muriate of ammonia*), iron, mercury (*calomel* and *corrosive sublimate*), zinc, antimony, silver, gold, platinum. The chlorides have a tendency to form double haloid salts: as the chloride of gold and sodium—chloride of ammonium and platinum, &c.

*Affinities.*—The affinities of the haloid group are very striking; they all form a large number of binary saline bodies like common salt—have a powerful affinity for hydrogen, producing a strong acid with it, in which the hydrogen is readily displaced by metals—have little affinity for oxygen, forming instable compounds. They also produce double salts of the same structure as those of chlorine. Of the series, chlorine appears to be the most active body, but they are all endowed with considerable electro-negative powers.

*Compounds.*—With oxygen chlorine forms four compounds.

Hypochlorous acid . . . .	ClO	Chloric acid . . . .	ClO <sub>5</sub>
Chlorous acid . . . .	ClO <sub>4</sub>	Perchloric acid . . . .	ClO <sub>7</sub>

With hydrogen there is formed a highly important body—chloride of hydrogen, HCl.

#### COMPOUNDS OF CHLORINE WITH OXYGEN.

*Hypochlorous Acid.* ClO; eq. 43.48.—It is a gaseous acid, of a yellow color, powerfully caustic, and possessing remarkable bleaching properties, but instable. The bleaching and disinfecting compounds called chlorides of lime and soda, are salts of hypochlorous acid, and evolve chlorine when exposed to the air, or acted on by acids.

*Chlorous Acid,* ClO<sub>4</sub>, is an explosive yellow gas, of no utility.

*Chloric Acid.* ClO<sub>5</sub>.—This is a viscid yellow liquid of an instable nature; one of its salts, the chlorate of potash, is much used as a source of oxygen.

*Perchloric Acid,* ClO<sub>7</sub>, is a deliquescent crystalline body, sometimes used as a test for potash, with which it forms a salt of sparing solubility.

*Note.*—There is little importance or stability in the oxygen compounds of the haloid series. Iodine forms an iodic (IO<sub>3</sub>) and periodic acid (IO<sub>7</sub>) of the same type as the chlorine acids, but of no value. Bromine forms the bromic acid (BrO<sub>5</sub>) only; and no oxide of fluorine is known at present.

## CHLORINE WITH HYDROGEN.

**CHLORIDE OF HYDROGEN**—*Hydrochloric Acid*—*Chlorohydric Acid* (Thenard and Hare)—*Muriatic Acid*. Symbol  $\text{HCl}$ ; eq. 36.47.—A pungent acid gas emitted, mixed with other bodies, from volcanoes. It is obtained in large quantities for manufacturing purposes by the action of sulphuric acid on sea salt ( $\text{Na}, \text{Cl}$ ), at a considerable temperature. The gaseous acid thus obtained is conducted into vessels containing water, and sold in solution. The changes in this case are simple,  $\text{H} + \text{SO}_4$  and  $\text{Na} + \text{Cl}$  become  $\text{Na} + \text{SO}_4$  and  $\text{H} + \text{Cl}$ ; the latter of which is chloride of hydrogen, and the former sulphate of soda.

For experiment, the gaseous acid can be obtained by gently heating the commercial solution.

**Characters.**—A colorless, pungent, acid gas, forming white vapors in the air, sp. gr. 1.269. Water dissolves 418 times its bulk at  $60^\circ \text{F}$ ., becoming powerfully acid; when concentrated, it has a sp. gr. of 1.21, and contains 42 per cent. of acid. The gas may be liquefied by a pressure of 40 atmospheres.

**Properties.**—A caustic, irrespirable gas, with all the properties of an acid when in the moist state. It has an intense affinity for water. The hydrogen of this compound is readily displaced by metals, especially when they are presented in the form of oxide; water and a chloride being simultaneously formed. It is not known to act directly as an acid. The solution of commerce is usually stained yellow with iron, and is otherwise impure. Muriatic acid disorganizes the blood, and is therefore an active poison.

**Tests.**—The gaseous acid fumes in the air, and produces with ammoniacal gas, dense vapors of chloride of ammonium. In solution it is precipitated as a white curdy body, by nitrate of silver, forming the chloride of silver, which is dissolved by ammonia, and blackens in the air.

**Uses.**—Muriatic acid is much used in manufactures; mixed with one-half its bulk of nitric acid, it forms *aqua regia*, or *nitro-muriatic acid*, which evolves nascent chlorine, and has the property of dissolving gold, platinum, and other metals. Muriatic acid is used in medicine in a dilute state as a tonic and febrifuge, especially in typhoid affections. In cases of over doses, it is to be met in the same way as nitric or sulphuric acid. The strong acid is powerfully escharotic, and in a state of dilution, may be used as a rubefacient or stimulating topical application. The vapor is very irritating, producing coughing, a difficulty of breathing, and inflammation of the air-passages when inhaled too freely.

The *nitro-muriatic acid* has been much commended in hepatic obstructions, unattended by fever. It is used internally in doses of four to ten drops properly diluted, especially in chronic affec-

tions of the liver, cutaneous diseases, obstinate constipation and secondary syphilis. Sponging the body under the arms and about the thighs with a solution containing about one part of acid to 60 of water, is often efficacious in arousing the action of the liver and bowels. It excites a prickly sensation in the skin, and if used several times, affects the salivary glands producing copious ptyalism. The *nitro-muriatic acid bath*, or Dr. Scott's bath, is highly valuable in the above cases, especially in warm climates, when inflammation is absent. It is usually administered as a pediluvium, but steady sponging answers equally well. In old cases a bath for the whole body is prepared. It is made in a narrow wooden vessel, and contains  $4\frac{1}{2}$  to 6 ounces of acid to about 3 gallons of water. The strength had better be cautiously increased from 3 ounces, lest the excitement be too great at first. In these baths, chlorine is evolved, and the action is principally due to its absorption, but the counter-irritation on the skin appears also to be serviceable.

**OTHER BINARY COMPOUNDS OF CHLORINE.**—Chlorine unites with nitrogen, forming the *Chloride of Nitrogen* ( $\text{NCl}_3$ ), which is a violently explosive compound; it is oleaginous, yellow and very irritating. There are three chlorides of carbon,  $\text{C}_4\text{Cl}_4$ — $\text{C}_4\text{Cl}_5$ —and  $\text{C}_4\text{Cl}_6$ , which are oily and crystalline bodies of no known utility. Chlorine also combines with sulphur, phosphorus, silicon and boron.

## IODINE.

*Symbol, I. Equivalent, 126.6.*

This element is found only in the sea, its products, especially fuci and sponges, and saline springs, in the compound state, usually as iodide of sodium and magnesium. It is obtained from the ashes of sea weed.

**Characters.**—A black, soft, crystalline solid with some metallic lustre. Its crystals are scaly, and consist of elongated octahedrons with a rhomboidal base; its sp. gr. is 4.948. It fuses at  $225^\circ$ , and the liquid boils at  $347^\circ$ , evolving a deep violet vapor, which readily condenses into crystals. Iodine is, however, volatile at all temperatures, and the density of its vapor is 8.716. It dissolves in about 7000 parts of water, but is readily taken up by alcohol or a solution of iodide of potassium or sodium.

**Properties.**—It is elementary, acrid, stains the skin of a fugitive yellow, and has nearly all the activity of chlorine on metallic and organic bodies. Its vapor supports the combustion of phosphorus and some metals, but it is itself not inflammable. Its binary compounds, which are numerous, are chiefly with hydrogen and the metals, and are called *Iodides*. They are formed

directly, or by bringing the metallic oxide in contact with iodide of hydrogen (HI), when the metallic iodide and water are formed.

The compounds of iodine with gold, silver, and some of the rarer metals, are singularly affected by sunlight, and are employed, especially the yellow iodide of silver, for making Daguerreotypes. A silver plate being exposed to the vapor of iodine in a dark place, is made to receive the image of a scene or person in the camera obscura, and its coat of iodide is affected in proportion to the intensity of the light falling on it. The plate being now exposed to the vapor of mercury, a picture is produced, and all that remains is to wash off the remaining iodide by a warm solution of hyposulphite of soda.

*Tests.*—The violet vapor, the black, shining and soft solid are characteristic. In solution, free iodine is discovered, by striking a blue color with a cold solution of starch. The soluble iodides are first treated with a little chlorine, which liberates the iodine, and then the solution of starch is used.

*Salts.*—Iodine, like chlorine, forms binary salts chiefly; of which the iodide of potassium, sodium, silver, iron and mercury are the most important.

*Uses.*—It is employed in the Daguerreotype and in medicine. Iodine is of an acrid taste, caustic and irritant; it is readily absorbed into the system, whether applied internally or externally. It is administered internally, dissolved in solution of iodide of potassium (*hydiolate of potash*). The dose is from  $\frac{1}{4}$  grain to two or more grains. In long-continued small doses, it appears to impede nutrition, whilst it excites the secretions; indeed, the bowels are usually free, and there may be ptyalism. There is wasting, which affects all the glands, especially if they be abnormally excited.

Hence it is almost a specific in bronchocele, scrofulous swellings, chronic enlargements of the liver, and it is to be steadily tried in scirrhus of any part of the body. It is also indicated in chronic inflammation, with thickening of the texture, or where there is excessive action, as of the heart; but it is not safe to employ it in active inflammatory affections. Too long-continued, it may produce colic and nausea, and in this case is to be employed externally in the form of ointment or liniment. Its so called alterative action is similar to that of calomel and chlorine.

It is also extensively employed as a topical application to skin diseases, erysipelas, and has been recommended for the purpose of hindering the changes of the small-pox pustule, or causing them to abort. Its action on the small-pox is remarkable, the pustules becoming dry soon after their appearance, when washed with a solution of the tincture, and in many cases leaving no pits on the skin. For this application of iodine, we are indebted to Dr.



Samuel Jackson, of Philadelphia, late of Northumberland County, Pennsylvania.

*Poisoning.*—It is an irritant poison, and also produces palpitation, restlessness, diarrhœa, nervous prostration, syncope. In one case, it caused death after six weeks' sickness. But it is not as poisonous an agent as formerly supposed. Nor is that nervous state, with gastric irritation and nausea, termed *iodism*, at all frequent, although the medicine has been long continued in doses of several grains a day. In cases of poisoning, white of eggs and amylaceous demulcents are to be used, for the latter form the inert blue compound already mentioned as a test for iodine. The stomach is to be emptied by the pump, and the subsequent treatment for nervous depression and gastro-enteritis to be conducted on general principles.

*Binary compounds of Iodine.*—With oxygen it forms iodic acid ( $\text{IO}_5$ ) and periodic acid ( $\text{IO}_7$ ), neither of which is of medical value. With hydrogen it forms iodide of hydrogen ( $\text{HI}$ ), a body analogous to chloride of hydrogen. It also combines with sulphur, phosphorus, nitrogen, chlorine and bromine; but these are of little importance, instable, and not known in medicine.

**IODIDE OF HYDROGEN**—*Hydriodic Acid.*  $\text{HI}$ ; eq. 127.6.—This is a pungent gaseous acid, fuming in the air, very soluble in water, and closely resembling hydrochloric acid. Brought in contact with most metallic oxides, it is decomposed, its hydrogen being replaced by the metal, and the free oxygen and hydrogen combining to form water.

It has been recommended by Dr. Buchanan as an advantageous means of administering iodine, but according to his experiments, possesses too little power, he having used as much as two drachms of iodine in this form during the twenty-four hours.

#### BROMINE.

*Symbol, Br. Equivalent, 78.39.*

This is like iodine found only in the ocean, its products, and saline springs. It is extracted from the bittern or lees of salt.

*Characters.*—A brown, fetid fluid, of sp. gr. 2.99. It solidifies at  $-4$ , and boils at  $113^\circ \text{F.}$ , throwing off reddish-brown vapors. It is highly volatile, and has to be kept under the surface of water.

*Properties.*—It is a supporter of combustion to some extent, the substances uniting with it being converted into bromides. In contact with water it has bleaching powers, and in other respects, closely resembles chlorine. It is caustic and irritating, and seems to possess the same therapeutical action as iodine, but is not used. The antidotes are the same.



*Tests.*—Its volatility, odor, and action on starch in giving it a yellowish color, as well as its solubility in ether, are characteristics of free bromine. The soluble bromides are precipitated, as a white curdy mass, by solution of nitrate of silver. The fresh precipitate is soluble in ammonia, and evolves the vapor of bromine if warmed with chlorine water.

*Salts.*—The bromide of potassium has been used as a substitute for the iodide of potassium in double the dose. The bromide of silver is employed in the Daguerreotype.

*Uses.*—It is used in the Daguerreotype, and may be occasionally employed in medicine.

*Compounds.*—It forms a gaseous acid with hydrogen, the *bromide of hydrogen*, or *hydrobromic acid*,  $\text{HBr}$ , which is very analogous to the iodide and chloride of hydrogen. With this the bromides may be formed by the substitution of the hydrogen by a metal. With oxygen the bromic acid,  $\text{BrO}_3$ , an instable body, is formed. Bromides of iodine, phosphorus, and sulphur also exist.

#### FLUORINE.

*Symbol, Fl. Equivalent, 18.7.*

It has not been isolated; but its compound with hydrogen, *fluoride of hydrogen*, or *hydrofluoric acid*,  $\text{HFl}$ , is well known. This is an extremely caustic, volatile acid, possessing the remarkable property of corroding glass, and hence may be used for etching on that material. It is very soluble in water, and a solution is sometimes kept in lead or silver vessels as a test for silica.

It is powerfully electro-negative, and combines with nearly all the metals, but none of the compounds are used. The fluoride of calcium is a common and beautiful mineral called Derbyshire spar, and is also an ingredient in the teeth and bones of animals.

No oxygen compound is known; the fluorides of sulphur and phosphorus are dense volatile fluids.

### THE PHOSPHORUS GROUP.

#### PHOSPHORUS—ARSENIC—ANTIMONY.

In this important group, Prof. Graham also includes nitrogen. These bodies occupy a low rank as electro-negative elements, and are distinguished from the metals in not forming salifiable bases, except in the case of antimony. They are distinctly isomorphous, and are strikingly associated in their gaseous hydrogen compound, as well as in some of their acids.

## PHOSPHORUS.

*Symbol, P. Equivalent, 31.44.*

The equivalent is by Berzelius taken at 15.72, or half the above. Phosphorus does not exist in nature in the elementary form; but in the state of combination, is found in minerals, plants and animals. It is one of the most important organic bodies. For commercial purposes, it is obtained from bones, which contain the phosphate of lime. The bones are calcined and treated with dilute sulphuric acid; the solution is strained, mixed with pounded charcoal, and when dry heated in a stone-ware retort to a white heat. Phosphorus passes over in vapor, and is condensed under water.

*Characters.*—It is a translucent, almost colorless solid, of the consistence and appearance of wax. It smokes in the air, and emits a yellowish light in darkness, exhaling a smell resembling that of volatilizing arsenic. It is brittle at 32°, melts at 113° and boils at 572° F., distilling over unchanged when oxygen is absent. Its sp. gr. is 1.77.

But when colorless phosphorus is exposed to light, it acquires a red color, and becomes crystalline, being converted into the  $\beta$  (*beta*), or inactive state of this element.

It is found in commerce in small sticks, which are made by casting the melted phosphorus, but it may be procured in dodecahedrons by evaporating its solution in sulphuret of carbon.

*Properties.*—It readily inflames at 113° F., and has to be kept under water; in the vapors of iodine and bromine, and in chlorine, it is spontaneously combustible. In these cases, iodides, bromides, &c., of phosphorus are formed. It dissolves in oils, ether and sulphuret of carbon, imparting a luminous appearance to these fluids in the dark. The vapor, which rises from phosphorus at common temperatures in the air, is phosphorous acid,  $\text{PO}_3$ ; but when it is burnt, it forms anhydrous phosphoric acid,  $\text{PO}_5$ . It combines with the metals, forming phosphurets or phosphides.

*Tests.*—Its great inflammability, waxy appearance, and phosphorescence are characteristic.

*Compounds.*—The phosphuret of calcium is employed to obtain phosphuretted hydrogen. Several phosphurets exist in nature, but are not employed in the arts or in medicine.

*Uses.*—It is used in the manufacture of friction matches, and sparingly in medicine. For medicinal purposes, the phosphorus should be dissolved in olive or almond oil in preference to ether, which will volatilize, and leave the inflammable solid in contact with the stomach. It has been used in doses of  $\frac{1}{20}$  to  $\frac{1}{10}$  of a

grain, as a nervous stimulant, in which respect it is said to be superior to any known medicine, in the typhoid states which follow some fevers, in nervous debility, paralysis, and diseases arising from an enfeebled state of the body. \* It is said to be a powerful aphrodisiac. It should always be given with a large amount of oil or a demulcent body, for the free element is poisonous.

*Poisoning.*—Two or three grains of common phosphorus are said to have produced death, whilst upwards of sixteen have failed to do so. This discrepancy may arise from the condition of the stomach, and the supervention of vomiting. It produces violent inflammation of the stomach and intestines, with purging and vomiting. The treatment should be directed to the evacuation of the poison, and administration of demulcents to defend the mucous membrane of the stomach and intestines.

**PHOSPHORUS WITH OXYGEN.**—It forms four compounds with oxygen, of which the phosphoric acid is the only one of importance; they are as follows:—

Oxide of phosphorus= $P_2O$   
Hypophosphorous acid= $PO$

Phosphorous acid= $PO_3$   
Phosphoric acid= $PO_5$

*Oxide of phosphorus* is a yellowish-red powder, which may be formed by burning phosphorus in a stream of oxygen under water.—*Hypophosphorous* acid is formed when phosphorus is boiled in alkaline solutions; it is little known.—*Phosphorous acid* is obtained by the slow combustion of phosphorus in air, and is a powerfully deoxydizing agent.

**PHOSPHORIC ACID.** Symbol, as usually written,  $PO_5$ ; eq. 71.44.—There are four compounds included under the general name of phosphoric acid. These are:—

Anhydrous phosphoric acid  $PO_5$

Monobasic phosphoric acid (*metaphosphoric acid*)  $PO_5 + HO$  or  $H + PO_6$

Bibasic phosphoric acid (*pyrophosphoric acid*)  $PO_5 + 2HO$  or  $H + PO_6 + HO$

Tribasic phosphoric acid (*common phosphoric acid*)  $PO_5 + 3HO$  or  $H + PO_6 + 2HO$ .

*The anhydrous phosphoric acid* is obtained by burning phosphorus in an abundance of air or dry oxygen gas. It is a white solid, possessing an intense affinity for water, with which it hisses; it is converted by this union into the tribasic acid. Once formed, no degree of heat is capable of separating all the water; but at less than  $400^\circ F.$ , one of the three atoms is driven off, and the *bibasic acid* is produced;—a full red heat drives off a second atom, and there is formed the *monobasic* or *glacial* phosphoric acid. This retains its structure at the highest temperatures, and is the radical compound; hence we prefer writing the formula of these

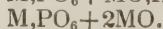
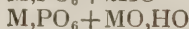
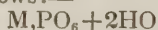
acids  $H+PO_6$  and  $H+PO_6,HO$ , &c., to making it  $H+PO_6$ ;  $2H+PO_7$ ;  $3H+PO_8$ , as is done by some authors.

The anhydrous body, spoken of above, cannot be called an acid, for it does not combine either with metals or metallic oxides. It is fixed, excepting as respects water. Of the three acids, the tribasic is the common product where water is present, the other two being instable, and convertible by boiling into the tribasic form. But monobasic or pyrophosphoric acid is the active body at high temperatures, and exists in minerals.

A solution of either of these acids in combination with soda produces a characteristic precipitate with nitrate of silver. The monobasic phosphate throws down a white gelatinous precipitate. The bibasic phosphate is white, and contains two atoms of silver, which may be represented in the formula  $Ag_2PO_6+AgO$ . The tribasic phosphate throws down a canary yellow body, which is, according to the above notation,  $Ag_3PO_6+2AgO$ .

The phosphates of the body, of animals and of plants, are tribasic, and in the ordinary reactions of chemistry, it is the form which is present. It may be obtained by cautious evaporation in deliquescent crystals, is intensely sour, reddens litmus, is very soluble in water, and is not caustic. In very large amounts, and in the concentrated state, it is said to be a corrosive poison, and is to be treated by the same means as nitric acid.

It forms three series of salts, one in which the hydrogen only is replaced by another metal, another in which an atom of  $HO$  is also replaced, and a third in which the hydrogen and both atoms of water are replaced. The bases may be different in these cases. The salts will be as follows:—



In which  $M$  represents a metal or compound electro-positive radical, as ammonium. Soda presents instances of these three forms.

The tribasic phosphate of soda with alkaline reaction  $Na_3PO_6+2NaO$

The neutral tribasic phosphate  $=Na_2PO_6+NaO+HO$

The tribasic phosphate with acid reaction  $=Na_3PO_6+2HO$ .

All these precipitate the nitrate of silver of a canary yellow color. These salts are remarkable, and closely connected with the functions of the human body. One of them plays the part of an acid, and is found in the gastric juice, giving to that fluid acidity; and the alkaline phosphate is present in the saliva, blood, chyle and lymph, and endows these and other fluids of the body with alkalescency.

*Uses.*—The tribasic phosphoric acid is the only one used; it has been recommended as a tonic, refrigerant and febrifuge, in the



dose of one to three grains in a weak solution. It does not appear to be superior to the common mineral acids; but is much milder, and less apt to disagree. It has been also recommended in caries and other diseases of the bones; as a nervous sedative, and for other purposes, but is little employed.

*Salts.*—The tribasic phosphate of soda is employed as a chemical reagent, and the phosphate of soda and oxide of ammonium (microcosmic salt) in blowpipe analysis. The latter is a tribasic phosphate, in which an atom of oxide of ammonium takes the place of an equivalent of water; its formula is  $\text{Na}_3\text{PO}_6\cdot\text{NH}_4\text{O}$ , HO. The tribasic phosphate of soda with alkaline reaction,  $\text{Na}_3\text{PO}_6\cdot 2\text{NaO}$ , exists throughout the fluids of the human body, giving them an alkaline reaction. The tribasic phosphate with acid reaction,  $\text{Na}_3\text{PO}_6\cdot 2\text{HO}$ , exists in the gastric juice, is said also to be present in the fluid derived from the muscles by pressure, and to give healthy urine its acid reaction. Bone earth contains two tribasic phosphates of lime, and has the following composition,  $\text{Ca}_3\text{PO}_6\cdot 2\text{CaO} + \text{Ca}_3\text{PO}_6\cdot \text{CaO}\cdot\text{HO}$ ; in combination with two atoms of water of crystallization, it forms a hard, smooth and pale brown calculus.

The ammoniaco-magnesian phosphate of the urine and of calculi is a tribasic phosphate, in which an atom of oxide of ammonium takes the place of an equivalent of water; its formula is  $\text{Mg}_3\text{PO}_6\cdot\text{MgO}\cdot\text{NH}_4\text{O}$ , and when crystallized, it contains 19 Aq. The common fusible calculus, so called because it fuses into a clear globule before the blowpipe, is a compound of this body and bone earth; this form of calculus often attains a great size, and is found in old and exhausted patients. The tribasic phosphates of ammonia and potash are also found in the human body.

In plants, the tribasic phosphates, especially of potash, soda, lime and magnesia, play an important part. They are invariably found in the seeds of the cerealia, and no mature grains are produced where phosphates are absent in the soil. Corn, wheat, and the varieties of the bean, contain phosphates almost exclusively in their meal, and owe some portion of their nutritiousness to the presence of these salts. For the production of abundant crops of grain, it is necessary the soil should be naturally rich in these salts, or that manures containing them be applied. And as they are but sparingly present, they are soon exhausted by a succession of grain crops; when bone earth and specimens of lime which contain phosphates are found to be the best amendments.

But plants possess an interesting action on the phosphates supplied to them from the soil; they decompose them to a limited extent, reducing the phosphorus. This enters into combination with a certain proximate principle (proteine) to form fibrine and albumen. The phosphorus of these nutritious bodies discharges the most

important functions in the frame of animals, being in process of time reconverted into phosphoric acid by oxydation, and serving to increase the amount of phosphates in the urine. All the phosphates are soluble in the strong acids.

*Uses.*—Phosphorus is procured in the arts from burnt bones which furnish phosphate of lime. Crushed bones are also abundantly employed in agriculture. The phosphates of soda and microcosmic salt are used in analysis. The phosphates of soda and iron have been introduced into medicine; the former is termed *tasteless purging salt*, and is an agreeable laxative in doses of two drachms to half an ounce, and an active purge in doses to one ounce or more; the iron salt is of little importance, being very insoluble, but it is said to be a mild chalybeate.

We take this opportunity of turning the attention of the profession to the remarkable properties of the tribasic phosphate of soda with acid reaction ( $\text{Na}_3\text{PO}_4 \cdot 2\text{H}_2\text{O}$ ), in endowing the gastric juice with its power to digest animal food, and as a solvent in the urine. It appears to us that it is worthy of trial in cases of dyspepsia, and as a solvent of those varieties of calculus which contain phosphates. It is readily prepared by digesting common phosphate of soda in a solution of phosphoric acid.

**PHOSPHORUS WITH HYDROGEN.** *Symbol*  $\text{H}_3\text{P}$ .—There are two gases having this composition, one spontaneously inflammable in the air, the other not having this property, but distinguished by a disagreeable odor resembling that of garlic. These are isomeric, and owe their difference to the allotropic state of the phosphorus, the inflammable body being a compound of *alpha* phosphorus, and the other of *beta* phosphorus.

They are obtained by warming the phosphuret of calcium with water, when the phosphorus of the calcium unites with the hydrogen of water forming the gas, and the calcium combining with the oxygen of the decomposed water forms oxide of calcium, or lime.

The gas is colorless, and in the *alpha* form bursts into flame on coming in contact with the air or oxygen. The combustion is attended with the production of beautiful wreaths of white smoke, consisting of phosphoric acid. It is sparingly produced over marshes, and when inflamed, constitutes the *ignis fatuus*, or “Will-with-the-wisp,” spoken of by travellers.

## ARSENIC.

Symbol, As. Equivalent, 74.34.

Arsenic has the appearance of a metal, but forms no basic oxide. It is found in the elementary state as a rare mineral, but is abundant in combination with cobalt, copper, iron, and other metals, forming arseniurets with these bodies. It also exists in the form of native arsenious acid, and as arseniates. The equivalent is sometimes taken at half the above number.

*Characters.*—Elementary arsenic, or, as it is called by Professor Pereira, *Arsenicum*, is a black solid of metallic appearance and lustre, very brittle, crystallizing in rhombohedrons; its sp. gr. is 5.88. It sublimes at  $356^{\circ}$  F., without previous fusion, into a crystalline mass.

*Properties.*—It possesses all the properties of an electro-negative body, combining with most metals to form arseniurets, which are frequently of a white metallic appearance. Its alloys are brittle. When produced by the action of charcoal upon arsenious acid, it evolves a garlic-like odor, but this does not belong to the metal. It tarnishes in moist air, and becomes slowly oxydized. In the elementary state, arsenic is not poisonous, but the facility with which it changes renders it a disagreeable substance at all times. It is employed in a few alloys.

*Tests.*—Its rich, black and lustrous appearance, high degree of volatility, and capacity of subliming without fusion, are characteristic. But it may be advisable to warm it in an open tube, subject to a current of air, by which it is sublimed and converted into a white crystalline powder, arsenious acid. The degree of heat,  $356^{\circ}$  F., enables us to distinguish it from antimony, which does not sublime short of a white heat, which no glass tube is capable of withstanding without fusion.

*Compounds.*—The most important compounds of arsenic are as follows:

The suboxide (*fly powder, or black oxide*).

Arsenious acid (*white arsenic*),  $\text{AsO}_3$ .

Arsenic acid,  $\text{AsO}_5$ .

Arseniuretted hydrogen,  $\text{H}_3\text{As}$ .

Bisulphuret of arsenic (*Realgar*),  $\text{AsS}_2$ .

Tersulphuret of arsenic.—*Sulphursenious acid (orpiment)*,  $\text{AsS}_3$ .

There are also a chloride, iodide, bromide, and fluoride.

**THE SUBOXIDE OF ARSENIC.**—This is a black dull powder, into which arsenic resolves itself by long exposure to the air. It has not been analyzed, and many suppose it to be a mixture of arsenious acid and the element, because it is resolved into these bodies

by sublimation. But the fly-powder of the shops, which is most culpably employed, exposed with water and sugar in saucers, for the purpose of killing flies, is not a uniform product, but usually a mixture containing arsenious acid, sulphur, lamp black, and other bodies. It is often the cause of poisoning, in which cases, the treatment and examination indicated for arsenious acid are necessary, inasmuch as the injurious effects arise from this body.

**ARSENIOUS ACID—*White Oxide of Arsenic—White Arsenic.***  
Symb.  $\text{AsO}_3$ ; eq. 98.34.—It is found as a rare metal in the native state, but is obtained in large quantity for commercial purposes, by roasting the ores of iron, and cobalt, which contain it. The arsenious acid is obtained by the action of the oxygen of the air on the metal, and sublimes in flues built for the purpose. This coarse product is next purified by a careful re-sublimation.

**Characters.**—It appears in commerce in two forms, as translucent slabs of a light yellowish tint and glassy appearance, and in opaque white porcelainous lumps, with a conchoidal fracture, and frequently translucent interiorly. The translucent variety passes into the opaque, the difference depending upon crystalline figure, for this acid possesses dimorphism, and the former consists of large right rhombic prisms, whilst the white acid is made up of minute octahedrons. There is a slight difference in the solubility and sp. gr. of the two—the transparent having sp. gr. 3.74, and 100 pts. of boiling water dissolving 9.68 parts; whilst the opaque has sp. gr. 3.69, and boiling water takes up 11.47 per cent. A solution of the vitreous acid reddens litmus paper, whilst that of the opaque does so but slightly. The taste of arsenious acid is scarcely appreciable, but it leaves an acrid sensation on the tongue. It is volatile, subliming without fusion at  $380^\circ \text{F.}$ ; its vapour is very dense, inodorous, and is soon condensed. When the sublimation is slow, brilliant octahedrons are obtained, which are very characteristic of this body. The powder of arsenious acid is of a dull white.

**Properties.**—Arsenious acid dissolves in the alkaline solutions, forming soft uncrystallizable arsenites. The acid is readily dissolved by hydrochloric acid; it is also dissolved by alcohol and oils, and but sparingly by cold water. It is not distinguished for chemical activity, and is readily reduced from its compounds by the action of charcoal and carbonate of soda with heat, being resolved into elementary arsenic and oxygen. But on organic bodies it possesses considerable activity, combining with them to form indestructible compounds; it is on this quality that its antiseptic and poisonous properties depend. The bodies of persons poisoned have been found almost perfect, but resembling mummies, long after their death. It is also destructive to vegetables.

**Tests.**—The powder mixed with three times its weight of re-



cently heated, but cold charcoal, and heated over a spirit lamp, in a test tube is reduced—a crust of metallic arsenic appearing about half an inch from the part occupied by the flame. This crust is of a steel-like appearance exteriorly, and readily sublimes by heat, being converted after two or three sublimations into a white crystalline powder of arsenious acid, which occupies the cooler parts of the tube. During the reduction, an odor of garlic is perceived by smelling at the top of the tube. The arsenical powder is also volatile in the open air without fusion. If the arsenious acid be in a clear solution, it may be examined by four means.

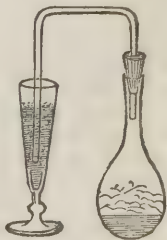
1. *The ammonio-nitrate of silver test. Hume's test.*—This test should be freshly prepared; it is made by cautiously adding solution of ammonia to a fresh and clear solution of nitrate of silver. The precipitate at first formed is to be redissolved by a further addition of ammonia until it is about disappearing. There must not be an excess of either ammonia or nitrate of silver, for in the first case arsenious acid will not be precipitated, and in the second a similar yellow precipitate will be produced with tribasic phosphoric acid or its soluble salts. When the test is properly prepared, it throws down arsenious acid in combination with silver (*arsenite of silver*) of a canary yellow color. This is a very satisfactory test in a pure solution, but of no value where other acids or saline matters are present.

2. *The ammonio-sulphate of copper test. Scheele's test.*—Add ammonia cautiously to a weak solution of sulphate of copper, until the precipitate first formed is just redissolved—too much ammonia destroys the test. This throws down a rich green precipitate with solution of arsenious acid, the arsenite of copper. This is a good test, but inapplicable in organic fluids which contain tannin, or are colored.

3. *The sulphuretted hydrogen test.*—Pass a stream of sulphuretted hydrogen through the solution, slightly acidulated with hydrochloric acid, and it will acquire a golden tint, (*the ter-sulphuret of arsenic*), which may be precipitated by boiling. The simple apparatus depicted in the figure will answer for this purpose; the generating bottle contains sulphuret of iron and dilute sulphuric acid.

This test is not of much use by itself, for solutions containing tin, cadmium, antimony and selenic acid, also yield yellow precipitates. But the yellow sulphuret of arsenic dissolves in ammonia, forming a colorless solution, which is not the case with the other precipitates. The most decisive test is, however, to collect the yellow precipitate, dry, mix

Fig. 52.



with charcoal and carbonate of soda, and place in the reducing tube, taking care to have the mixture quite dry. If arsenious acid be present, it will be reduced and form the black shining crust of elementary arsenic. This may be tested by re-sublimation, &c. If all the precautions pointed out be adopted, this test, which is, however, tedious, may be employed in detecting the poison in organic mixtures, as the contents of the stomach.

*The copper test.*—If strips of bright copper be boiled in pure hydrochloric acid, they are not tarnished, but if arsenic, antimony, bismuth, mercury, and a few other metals, be present, the copper is partly dissolved, and these metals precipitated on its surface. This is, perhaps, the most delicate test for the presence of arsenic in muriatic acid, as recommended by M. Runge—less than the  $\frac{1}{500}$ th of a grain having been detected by me in this way. It is to be remarked that both the muriatic and sulphuric acids of commerce occasionally contain arsenic, and they must be purified by this means, before use for the detection of this agent. The strip must not be heated too long, or the black scales of arsenic fall off.

The color acquired by the copper strip enables us, in some measure, to discriminate between these metals, but is not a safe test. The tarnished strips have to be carefully washed in warm water, dried, and then transferred to a small tube of Bohemian glass, drawn to a point at one end, but open. The flame of a spirit lamp is next made to travel over the tube so as to drive out all moisture. Heat is then to be applied near the pointed end to the metal, and slowly advanced until the metal is made nearly red hot. If any arsenic be present, it will be found about half an inch in advance of the metal, in brilliant octahedral crystals of arsenious acid.

These cannot be mistaken for any other substance, but as mercury may be present in the contents of the stomach, and would be sublimed, although not as a crystalline white body, it is well to cut the tube with a file below the sublimate, and dissolve it in boiling distilled water. The solution may now be tested by the ammonio-nitrate of silver and the ammonio-sulphate of copper. Or the sublimate may be separated, mixed with freshly burnt charcoal, and reduced for the purpose of obtaining the metallic crust.

These manipulations are simple, and may be expeditiously made; they also enable us to discriminate between any medicines, which may be present in the stomach of the deceased,\* and the poison. For this purpose the other fluid tests are useless, and

\* The reader will find every particular on this subject, in my paper on the introduction of this test into medico-legal inquiries. See *The American Journal of Science (Silliman's)* for January, 1842.

considering all things, I have more confidence in this test than in any of the preceding, or in Mr. Marsh's, which follows.

Hence I proposed its introduction into medico-legal investigations in January, 1842, and find that Professor Christison has adopted it, but without mentioning my communication, which was reprinted in the *Edinburgh Philosophical Magazine*, and seen by him, for he quotes passages from it.

*Marsh's test. The arseniuretted hydrogen test.*—The suspected fluid is in this case to be placed in a bottle, furnished with a cork and jette tube of glass, and mixed with zinc and dilute sulphuric acid. The dilute acid generates, by contact with the zinc, hydrogen gas, which unites with any arsenic present, and rises as arseniuretted hydrogen. The gas is colorless, has a garlic-like odor, and is readily inflammable, burning with a pale blue flame. It is to be set on fire as it issues—a smoke of arsenious acid is seen to rise from it, and if a clean piece of white porcelain, or a piece of glass, be held in the flame, a stain will be produced, consisting of a central black portion of metallic arsenic, surrounded by a white ring of arsenious acid. If the glass be held entirely above the flame, then the white deposit only is obtained. Identical appearances are obtained if antimony, or its compounds, be present in the fluid, but the black crust of metallic antimony does not sublime at the low heat at which arsenic is volatilized, and this furnishes us with a means of discrimination.

The figure (53) represents a simple apparatus for making this test. Fig. 54 represents Marsh's apparatus of the common figure.

Fig. 53.

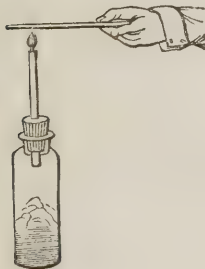
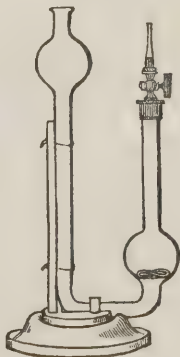


Fig. 54.

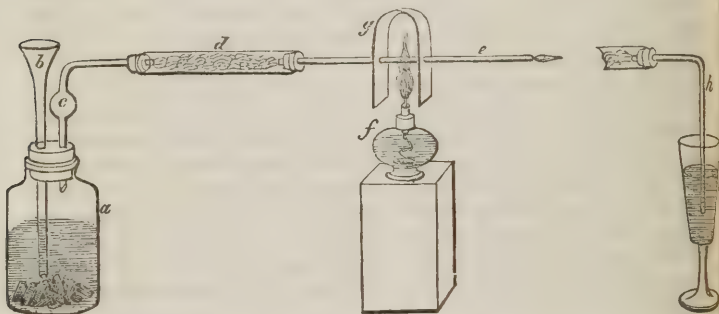


There are several objections to Marsh's test. It is not as delicate as the copper test recommended by me, for I have discrimi-

nated a  $\frac{1}{2500}$ th of a grain of arsenious acid, and Mr. Brett obtained  $\frac{1}{250}$ th as the minimum by Marsh's apparatus. The gases may explode. In organic mixtures, there is so much froth produced as to render the combustion impossible, unless additional manipulations be employed. For this purpose the organic matter is to be precipitated by nitrate of silver, or charred by heating with strong sulphuric acid. The products evaporated nearly to dryness, and then redissolved in pure water. Again, the zinc and sulphuric acid both occasionally contain arsenic.

Certain improvements have been made in this test by Liebig, Lassaigne, and others. The apparatus represents one of these improvements, Fig. 55.

Fig. 55.



*Description.*—The bottle *a*, or a two or three-necked bottle, is employed to generate the gas, and is preferable to Marsh's tube, for it enables us to operate on larger quantities, without using nitrate of silver or sulphuric acid to destroy the animal matter: fresh dilute sulphuric acid is readily introduced by the funnel *b*, the end of which passes nearly to the bottom of the generating bottle; *c* is the escape tube along which the arseniuretted hydrogen flows; the bulb is intended to condense any fluid which may rise, and the wide tube *d* filled with dry chloride of calcium or asbestos, answers a similar purpose, and hinders the passage of bubbles of froth. A small tube *e*, of *hard Bohemian glass, entirely free from lead*, is inserted into the condensing tube by a cork; it terminates in a jette. *G* represents a piece of platinum curved over the tube, and *f*, a spirit lamp, for the purpose of bringing the tube *e* to a red heat, and maintaining its temperature; by which any arsenic in the effluent gas is reduced, and collects in a metallic crust a little beyond the heated portion of the tube. The gas may also be inflamed at the jette. *H* represents another bent tube, which may be attached by a cork to the chloride of calcium tube, so as to conduct the gas into a test glass *i*.



The above apparatus is for the purpose of testing the effluent gas by heat, which causes any arsenic it contains to be precipitated as a metallic crust—but this effect also follows if antimony be present. Or the gas may be conducted through a solution of nitrate of silver, in which, if arsenic be present, a black precipitate falls, and a solution of arsenious acid with nitric acid is obtained. A little hydrochloric acid being added, any free nitrate of silver is precipitated, and the arsenious acid may be tested as before.

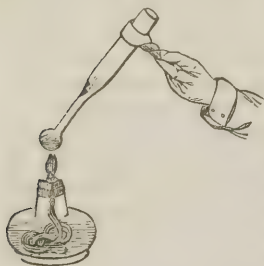
But, notwithstanding these improvements, Marsh's test is open to serious objections where organic matters are present, for if but a minute quantity of empyreumatic oil rise with the vapor, it will form a black stain at the heated part of the discharging tube. Messrs. Danger and Flandin find, also, that, when the direct test, by holding a white piece of plate or of glass over the flame, is employed, stains may be produced consisting of sulphite and phosphite of ammonia with carbonaceous matter.

*Conclusion on Testing.*—The collection of the arsenic from the body is effected by scraping the coats of the stomach, if any white powder be apparent thereon. Otherwise, the stomach is to be cut up into pieces and boiled with dilute hydrochloric acid, in a glass vessel. The contents of the stomach and matters vomited may also be boiled with the acid. It greatly assists the solubility of the arsenious acid. If the liver, kidney, or other viscus, is to be examined in cases of death from slow poisoning, it is cut up into fine pieces, and treated in the same manner. The clear portions are to be separated by straining with pressure through strong linen, and it will be well to add to the solids, after the first straining, a second or third dose of dilute acid, and this exhausts them of all arsenious acid. The liquid is now evaporated to a small compass. This is all that is necessary if my plan of using copper strips be employed; but if the further examination is to be carried on in Marsh's apparatus, another step is necessary. The concentrated solution is to be mixed with about  $\frac{1}{6}$ th of strong sulphuric acid, and heated to dryness, care being taken not to elevate the temperature to 300° F. A solution in boiling water is now made and filtered, and this is employed in the generating bottle.

The plan recommended by me is to collect the poison with copper, using strips three inches long and  $\frac{1}{8}$ d of an inch wide, boiling the muriatic acid solution upon them slowly, and removing the copper as soon as the exterior becomes black, and before the crust falls off. A number of strips may be used, and thus any amount of arsenic may be collected. These are next to be introduced into suitable subliming tubes, of as small a size as possible, and heated, as stated in the remarks on this test. A part of the arsenious acid may be next reduced with charcoal, and other portions tested with the salts of silver, and of copper, and also by sulphuretted hydro-

gen. When the amount of arsenious acid is small, Berzelius's test tube had better be employed in the reduction. Fig. 56 represents this vessel, and the method of using it.

Fig. 56.



Great care must be taken, in all the cases of reduction, that the glass be free from lead, which is stained of a black metallic color by heat, and that no particles of charcoal or empyreumatic matters be mistaken for the arsenical crust. To be certain on these points, the tube must be accurately cleaned with a piece of linen attached to a wire, until it is dry, and free from all stains.

If Marsh's test be preferred, the stain on white porcelain or glass is to be obtained, and subsequently examined by heat and solution as heretofore. No one test is sufficient, and in the courts of law, in the present day, it is expected that all methods of examination have been made.

One further practical observation is necessary before closing this part of the subject. It will be remembered that arsenic acid, which is equally, if not more poisonous, than arsenious acid, is isomorphous with the phosphoric acid. Orfila asserts that the arseniate of lime is occasionally present in the bones and other tissues of the bodies of animals, and the thing is chemically probable, although subsequent and acute observers have not found it. The mass of evidence is against it; moreover, Orfila states that, in these cases, the arsenical substance is not as readily dissolved by hydrochloric acid as the adventitious compounds of arsenious acid.

*Uses.*—It is employed in the arts for making pigments; in agriculture, for preparing wheat seed to hinder smut, for which purpose it is very inferior to a solution of sulphate of copper or blue vitriol. It is also used to kill rats, vermin and human beings. In medicine it is employed externally as a caustic to malignant growths, especially onychia maligna, but it is often absorbed into the system, and produces dangerous symptoms, and even death. The danger appears to be greater when a small amount is used than a quantity sufficiently large to destroy the ulcerated surface. But the practice is always dangerous. Dilute solutions, especially of arsenite of potash, are used in some obstinate chronic diseases of the skin, as lepra, psoriasis, impetigo. Internally the arsenite of potash (Fowler's solution, or *Liquor Potassæ arsenitis*), is preferred; it is an admirable medicine in some forms of protracted intermittent, where quinine fails; it is also useful in chronic nervous diseases and cutaneous affections. It is readily absorbed

when introduced into the stomach in solution, and fatal effects may arise from a small quantity in this state. This medicine is extremely dangerous for two reasons: that it sometimes appears to produce no effects for a long time, and then suddenly acts with great violence, and secondly, because it produces chronic poisoning in the smallest doses, if long continued. It is never to be employed after headache, swelling of the eyelids, or other parts of the body, impaired digestion, and a sense of feebleness, are experienced.

*Poisoning.*—So little as four and a half grains of arsenious acid have produced death, but a fatal dose is probably ten grains, and several drachms have failed to do any harm, when received on a full stomach, and soon voided by emesis. Poisoning may occur from the external application of the acid or its soluble compounds. The symptoms produced in cases of acute poisoning, are, violent burning at the pit of the stomach, vomiting, thirst, bloody stools, irregular action of the heart, great prostration, clammy sweats, trembling of the limbs, cramps, sometimes delirium and death. But there may be little gastro-enteritis, the patient dying as though narcotized, or in convulsions and tetanized. Death occurs more rapidly in the latter cases, and it may take place in a few hours, or not until three or more days.

*Antidotes.*—Dependence cannot be placed on the antidotes for arsenious acid. The exhibition of the whites of eggs with farinaceous matters, or large quantities of olive oil, the production of vomiting, and use of the stomach pump, are the best methods of treatment in cases of poisoning. The principal difficulty in these cases arises from the arsenious acid becoming hidden in the folds of the stomach, and enveloped by mucus; hence large quantities of warm water, containing the white of egg, are to be repeatedly thrown into the stomach, and rapidly pumped up, for the worst effects of the poison arise from its absorption.

But whilst these are the essential means, it would be culpable, in the present day, to omit the use of the fashionable antidotes. These are lime water and the *hydrated peroxide of iron*. The first is not of much utility, from the slow action of the arsenious acid on it, and the same objection has been found against the second. The hydrated peroxide ought, however, to be used; it is made by adding solution of ammonia to the peracetate, perntrate, or any persalt of iron; the oxide at once falls as a red magma, and is to be thrown on a cotton filter, and washed once or twice with water. It should be fresh, or kept well-stopped, for the dry peroxide is useless. As we do not know how much poison has been taken, the necessary dose cannot be prescribed; but it is a perfectly innocent substance. Hence, give a tablespoonful, suspended in water, every three or four minutes, until the urgent

symptoms are relieved. To a child, a teaspoonful may be given with equal frequency. But do not throw aside the stomach pump to administer this antidote; rather employ it after the free use of that instrument.

The hydrated peroxide acts chemically on the poison, neutralizing it, and forming an arsenite of iron. But it has been clearly proved, that it attacks only the arsenious acid in solution, and has no effect on the solid particles which lie on the mucous membrane. It is, therefore, little efficacious, because arsenious acid is but sparingly soluble, and, in most cases, large amounts are introduced into the stomach for the purpose of poisoning.

*Salts.*—The arsenite of potash forms the basis of Fowler's solution, and the arsenite of soda of Pearson's solution; they are similar in properties. The arsenite of copper is the fine pigment called Scheele's green. An *arsenite of quinine* has been recently introduced into medicine as an antiperiodic in protracted intermittents. It appears to possess the action of both ingredients, and may be a useful medicine, but in no wise better than an extemporaneous combination of arsenious acid and sulphate of quinine.

**ARSENIC ACID.**  $\text{AsO}_5$ ?—This is obtained by boiling a solution of arsenious acid with nitric acid. It is a powerful acid, isomorphous with the tribasic phosphoric acid, highly poisonous, and somewhat soluble. It is distinguished in the free state, or in its soluble salts by throwing down a brick-red precipitate with nitrate of silver. It is not at present employed.

**ARSENIURETTED HYDROGEN.**  $\text{H}_3\text{As}$ ?—This is a violently poisonous gas; it may be prepared by putting pieces of zinc in a solution of arsenious acid, and then adding sulphuric acid. The hydrogen formed, reduces the arsenious acid and rises as arseniuretted hydrogen, more or less mixed with hydrogen.

*Characters.*—It is transparent, has the odor of garlic, sp. gr. 2.695, and is sparingly soluble in water.

*Properties.*—It burns with a pale blue flame in the air, becoming resolved into water and arsenious acid, when the combustion is free; but if this be conducted in a limited supply of air, water and elementary arsenic are produced. It is decomposed by being passed through a red hot tube into elementary arsenic and free hydrogen.

It is very poisonous, when inhaled even in small quantity, producing headache, nervous symptoms, a febrile state with œdematous swellings of the eyelids, face and other parts of the body. But as it is not used, poisoning never occurs by it except to the experimental chemist. This gas is generated in Marsh's test for arsenic, and it will be necessary to adopt precautions to escape



poisoning where the amount of arsenious acid is large, by conducting the process in the open air or under a flue.

**THE SULPHURETS OF ARSENIC.**—*Realgar* ( $\text{AsS}_2$ ) occurs native, and is readily made by heating its components; it is a red vitreous and insoluble body. It is employed in pyrotechny, and is in its commercial form a powerful poison. It is detected by the reduction test. The treatment is similar to that for the arsenious acid except that the antidotes may be dispensed with. *Orpiment*, or sulph-arsenious acid,  $\text{AsS}_3$ , is a fine yellow insoluble solid. It occurs native and is used as a pigment, and called *King's Yellow*. The commercial body contains arsenious acid, and is a poison. It is detected by the reduction test. In cases of poisoning the treatment is that for arsenious acid. It is employed in certain nostrums as a depilatory, as a paint and by pyrotechnists.

Two other sulphurets of the constitution,  $\text{AsS}_5$  and  $\text{AsS}_6$ , are known, but not employed. *Realgar*, *orpiment* and the pentasulphuret (sulph-arsenic acid)  $\text{AsS}_5$ , are sulphur acids, and combine with bases like the so called oxygen acids.

**OTHER BINARY COMPOUNDS OF ARSENIC.**—The *terchloride*,  $\text{AsCl}_3$ , is a very instable, oily and dense liquid, intensely poisonous. The iodide,  $\text{AsI}_3$ , is a red volatile and soluble crystalline body. It has been recommended as an external application in a diluted ointment (grs. iij to  $\text{ʒi}$  of lard) in tubercular skin diseases, but it does not appear to be superior to arsenious acid.

Mr. Donovan strongly recommends the *compound iodide of arsenic and mercury*. It is made by rubbing 6.08 grains of metallic arsenic, 15.38 grains of mercury, 50 grains of iodine, with  $\text{ʒi}$  of alcohol, until the mass is dry and of a pale red color. This is then dissolved in half a pint of water, and boiled with half an ounce of hydriodic acid for a few minutes. It is used in solution. The dose is  $\frac{1}{32}$ d to  $\frac{1}{16}$ th of a grain three times daily, and it is recommended in cutaneous affections, fungoid and other diseased growths.

#### ANTIMONY.

*Symbol (Stibium) Sb. Equiv. 129.2.*

Antimony is abundant as a sulphuret, which is readily reduced by heat and a flux containing carbon and potash or soda.

**Characters.**—It is a bluish white brittle body, lamellated or in rhombohedral crystals, and having considerable metallic brilliancy. Its sp. gr. is 6.7 to 6.8; it fuses at  $797^\circ$ , and is volatile at a white heat.

**Properties.**—It is a conductor of heat, and burns at a red heat when exposed to the air into an oxide. It is more electro-

negative in its relations to other bodies than the metals, and strikingly isomorphous with arsenic. It is employed in alloying some metals, and the compounds may be termed antimoniurets.

*Compounds.*—The most important compound is the teroxide  $\text{SbO}_3$ , which is the basis of tartar emetic. The binary compounds are as follows :

Teroxide of antimony ( <i>sesquioxide</i> )	-	-	-	$\text{SbO}_3$
Antimonious acid	-	-	-	$\text{SbO}_4$
Antimonic acid	-	-	-	$\text{SbO}_5$
Terchloride of antimony	-	-	-	$\text{SbCl}_3$
Perchloride of antimony	-	-	-	$\text{SbCl}_5$
Tersulphuret of antimony	-	-	-	$\text{SbS}_3$
Persulphuret of antimony ( <i>golden sulphuret</i> )	-	-	-	$\text{SbS}_5$
Antimoniuretted hydrogen	-	-	-	$\text{H}_3\text{Sb}$

**TEROXIDE OF ANTIMONY—*Sesquioxide—Oxide of Antimony.***  
 $\text{SbO}_3$ ; eq. 153.2.—It may be obtained by pouring the solution of antimony in hydrochloric acid (*Chloride of Antimony*) into water, and digesting the precipitate with solution of carbonate of soda.

*Characters.*—It is a whitish solid, having the same dimorphous crystalline forms as arsenious acid. The precipitated oxide is anhydrous, and fuses into a yellow liquid which concretes into a crystalline mass on cooling. It fuses before the blowpipe, and is volatile.

*Properties.*—It is scarcely a base, although it is found in tartar emetic and some few double salts. It is an active poison, depressing the powers of life, and is the active ingredient in the common antimonial preparations. It is used in the preparation of tartar emetic.

*Tests.*—It is dissolved by a solution of cream of tartar, which is converted into the *tartrate of potash and antimony*, or tartar emetic. Its fusibility into a yellow fluid seems to distinguish it from arsenious acid, which it resembles in most respects. The soluble forms of antimony are precipitated of an orange color by a stream of sulphuretted hydrogen, which does not, however, yield a metalline crust, as in the case of arsenic, by reduction, for antimony is not volatile short of a white heat.

*Compounds.*—It is found in uncertain quantities in the *pulvis antimonialis* and James' powder, the properties of these medicines depending upon its presence. The oxysulphuret, or *Kermes mineral*, is a compound of tersulphuret with teroxide  $2(\text{SbS}_3) + \text{SbO}_3$ . This is used as an alterative in doses of gr. i to gr. iij. But the principal compound is *tartar emetic*, or the tartrate of potash and antimony.

*Tartar emetic* is white, transparent, and crystallizes in rhombic octahedrons. It effloresces in the air. The taste is styptic and metallic, and it dissolves in about 14 parts of water at  $60^\circ \text{F}$ .

and in about 2 parts at a boiling heat. The solution slightly reddens litmus paper and undergoes spontaneous decomposition by keeping.

It is tested by the action of heat, which chars it, and by passing a stream of sulphuretted hydrogen through the solution when the orange red precipitate of tersulphuret is produced, which does not act like the sulphuret of arsenic in the reducing tube.

Tartar emetic is a diaphoretic, expectorant and nauseant in small doses (gr.  $\frac{1}{12}$  to gr.  $\frac{1}{2}$ ), emetic and purgative in the dose of gr. i, and in doses of gr. ii to gr. iv, often repeated, a powerful arterial sedative. In pneumonitis, it is a valuable medicine administered in doses beginning with gr. ss, and increasing it to gr. ij every two hours until sleep or considerable amelioration of the symptoms occurs. It produces great debility, relaxes the muscular fibres of the body, depresses the vital actions, and reduces the arterial capillary circulation.

It seldom acts as a poison, and is not used with that intention, but in cases of accident, vomiting should be encouraged, and tannic acid or astringent solutions administered. A strong ointment (3ii to 3i of lard) is a powerful vesicant, and diluted is stimulant. The medicine is absorbed into the system to a limited extent, and its antimony has been discovered in the viscera by Orfila, Barré and others. It is a dangerous medicine for young children, as it prostrates them too much.

**ANTIMONIOUS ACID.**  $\text{SbO}_4$ .—A grayish-white powder, infusible, not volatile, insoluble. It combines with the alkalies, but the antimonites are readily decomposed. It is the final result of the action of heat and air on elementary antimony.

**ANTIMONIC ACID.**  $\text{SbO}_5$ .—Procured by the action of strong nitric acid on antimony. It is insoluble; exposed to heat it acquires a yellow color, and it combines with the alkalies. It is decomposed by a red heat into antimonious acid and oxygen.

**TERCHLORIDE OF ANTIMONY.**  $\text{SbCl}_3$ .—A soft butyraceous solid, procured by the distillation of bichloride of mercury and sulphuret of antimony; it is deliquescent, and a solution in hydrochloric acid, dropped into water, produces a bulky precipitate, called the powder of *algaroth* or oxychloride of antimony ( $\text{SbCl}_3 + 3\text{SbO}_3$ ) + 3Aq. The *butter of antimony* is caustic, and the oxychloride emetic, but neither is much used except in the manufacture of the teroxide of antimony and tartar emetic.

**PERCHLORIDE OF ANTIMONY.**  $\text{SbCl}_5$ .—It is made by passing a current of chlorine over hot antimony, and is a heavy fuming liquid, of a bad odor, and readily decomposed.

**THE SULPHURETS.**—The tersulphuret,  $\text{SbS}_3$ , is an abundant mineral of a brittle texture, and striated dark gray metallic appear-

ance. When hydrated, it has an orange color, and is formed when a stream of sulphuretted hydrogen is passed through a solution of tartar emetic. By heating this body in a shallow iron vessel, and stirring until fumes are no longer given off, a gray powder is obtained which may be fused by a red heat, in a closed vessel, into a brown-red glass called the *vitrum antimonii*. This is a mixture of sulphurets and oxides. When the free oxide is dissolved by acids, there remains an *oxysulphuret*,  $\text{SbO}_3 + 2(\text{SbS}_3)$ , called the *crocus*, or *saffron of antimony*.

By boiling caustic potash on powdered tersulphuret of antimony, a solution is obtained that precipitates, as it cools, an orange red substance called *Kermes mineral*. This is a mixture of teroxide of antimony and sulphuret. If the hot solution be treated with an acid before its spontaneous decomposition, a brownish oxysulphuret is thrown down called the *orange sulphuret* (*Hepar antimonii*) or *precipitated sulphuret of antimony*. It is a good medicine, and employed as an alterative in the compound calomel, or Plummer's pill. The *golden sulphuret* ( $\text{SbS}_3$ ), *persulphuret* or *sulph-antimonic acid*, is obtained after the spontaneous precipitation of the *kermes*, by adding an acid to the antimonial solution in potash. It is of a lighter color than the other two bodies. There is also a sulph-antimonious acid ( $\text{SbS}_4$ ).

**ANTIMONIURETTED HYDROGEN.**—This gaseous body is procured by adding zinc and sulphuric acid to a solution of tartar emetic. Its formula is generally supposed to be  $\text{H}_3\text{Sb}$ . It burns with a white flame, throwing off a white smoke of oxide of antimony and water. It is reduced by passing through a red hot tube, depositing a metalline crust, at the heated point, which may be readily distinguished from arsenic by its want of volatility at a low red heat. If a white piece of plate be held low down in the flame of this gas, a black crust with a white border like that obtained under the same circumstances from the flame of arseniuretted hydrogen, is obtained, but they differ in the stability of the antimonial crust.

## CARBON.

*Symbol, C. Equivalent, 6.0.*

Carbon is the great organic element, no substance produced by the action of plants being without this body. It exists in nature as the diamond, anthracite and plumbago; and in a compound state in all animal and vegetable substances. It is obtained in an impure state as charcoal and lampblack, by burning vegetable bodies in the absence of air.

*Characters.*—Carbon has three allotropic states. 1. In the *dia-*



*mond* it is translucent, crystallizes in octahedrons, variously modified and with curved facets. Its sp. gr. is about 3.5, and it is the hardest mineral known. It appears from the researches of Dumas, that it has an organic structure, and is of vegetable origin. It is incombustible except in oxygen, and infusible. 2. *Plumbago* is unctuous to the touch, has a metallic lustre, is opaque, and almost incombustible. 3. Anthracite and lampblack are opaque, black, and readily combustible.

*Properties.*—The common or  $\gamma$  carbon is readily combustible, becoming converted in a full stream of oxygen into carbonic acid ( $\text{CO}_2$ ), and in a limited supply into carbonic oxide ( $\text{CO}$ ). It is a good radiator of heat, but a poor conductor of heat or electricity. The diamond possesses a high refractive and dispersive power for light. Charcoal being porous, possesses the property of absorbing gases and also of condensing many times its volume of several, especially ammoniacal and sulphuretted hydrogen gases; this endows it with disinfecting powers, and makes the powder useful in agriculture for the purpose of hindering the escape of many vaporous bodies from the soil. Ivory black, derived from bones burnt in iron retorts, also possesses the power of decolorizing organic solutions, as may be shown by filtering a solution of indigo through it. All the forms of carbon are infusible, and they act as electro-positive bodies in most cases, resembling in this respect the metals, but there are a few compounds of a different character with hydrogen, &c., called *carburets*.

*Tests.*—The test for carbon is its convertibility into carbonic acid by the action of heat and oxygen gas.

*Uses.*—The above varieties are used in various ways. The diamond is used as an ornament and to cut glass. Plumbago is employed in the manufacture of crucibles, for greasing machinery, and the finer sorts constitute the black lead of writing pencils. Ivory black is employed to decolorize solutions, and pounded charcoal to remove the putrescent odor of spoiled provisions or stagnant waters. Anthracite charcoal, &c., as fuel.

*Compounds.*—The principal binary compounds of carbon are:

Carbonic oxide	-	-	-	-	$\text{CO}$ .
Carbonic acid	-	-	-	-	$\text{CO}_2$ .
Light carburetted hydrogen	-	-	-	-	$\text{H}_2\text{C}$ .
Olefiant gas	-	-	-	-	$\text{H}_4\text{C}_4$ .
Cyanogen ( <i>bicarburet of nitrogen</i> )	-	-	-	-	$\text{C}_2\text{N}$ .
Bisulphuret of carbon	-	-	-	-	$\text{CS}_2$ .

**CARBONIC OXIDE.**  $\text{CO}$ ; eq. 14.0.—This gas is generated when charcoal is burnt in a limited supply of air.

*Characters.*—It is colorless, inodorous, sparingly soluble, sp. gr. 0.972. It has never been liquefied.

*Properties.*—This gas is inflammable, burning with a pale

blue flame into carbonic acid,  $\text{CO}_2$ . It is highly poisonous, acting in the same way as carbonic acid. It is by some considered an electro-positive compound radical, and unites, when exposed to light, with chlorine, forming a pungent acid body, called *chloro-carbonic* acid or phosgene gas. Carbonic oxide is not put to any use.

**CARBONIC ACID.**  $\text{CO}_2$ ; eq. 22.0.—This important gas exists in the air to the extent of 4 to 6 parts in 10.000; it is found in most waters, and is one of the most abundant products of the decomposition and combustion of animal and vegetable substances. It is readily obtained by adding hydrochloric acid to pieces of marble, which is a carbonate of lime; the carbonic acid rises as a gas, and may be collected by displacement. If it be wanted dry, the following apparatus (Fig. 57) will be necessary, in which the long central tube contains fused chloride of calcium, which absorbs any moisture which passes over.

Fig. 57.



**Characters.**—It is a colorless gas, of a pungent taste, and little odor. Its sp. gr. is 1.524; 100 cubic inches weighing 47.26 grains. Cold water dissolves about its own volume, but will take up large quantities under pressure; such solutions constitute the soda water of manufacturers. Under a pressure of 28 atmospheres, at  $32^\circ \text{F}$ ., it may be liquefied, and forms a colorless limpid fluid; when relieved of pressure, it immediately boils, and from the cold produced by its rapid evaporation, about  $\frac{1}{8}$ th becomes solid. Solid carbonic acid has the appearance of snow, and by its evaporation, produces intense cold. Mixed with ether, in vacuo, it depresses the thermometer to  $-165^\circ \text{F}$ .

**Properties.**—Carbonic acid possesses acid properties; its solution reddens litmus paper, and it unites with many bases, forming carbonates, which are, however, commonly decomposed by most acids, and also by heat. It is neither inflammable, nor a sup-

porter of combustion, and is totally irrespirable, a small amount bringing on narcotism, and destroying life by asphyxiating the animal.

*Tests.*—Its power to extinguish a flame, redden litmus, and cause a white precipitate of carbonate of lime, when passed through clear lime water, enables us to distinguish the gas. The effervescence produced by a weak acid on its compounds, with the above tests of the gas, enables us to discriminate the carbonates.

*Uses.*—Carbonic acid dissolved in water is a grateful stimulus to the stomach, especially in nausea. The gas is sometimes employed in the laboratory; also for purposes of suicide, especially amongst the French; and was formerly recommended as a proper medium for the preservation of fruits, &c. Its use in the operations of nature are more important, as it is the chief food of plants, which derive it from the air by their leaves; and, from fertile soils, in solution by their roots. It is also a product of the changes going on in the human body, and is present to the extent of four per cent. in expired air.

In cases of *asphyxia*, by carbonic acid from wells (choke damp), from cesspools, or from the incautious inhalation of the vapor of burning coals, the patient should be freely exposed to the air. The jugular veins should be opened, flannels wrung out of hot water applied to the body and extremities, and artificial respiration established. The gas introduced into the lungs should contain about one-eighth of protoxide of nitrogen if possible. For this purpose, the bellows should be placed in contact with a large Indian rubber bag, containing the mixed gases.

*Salts.*—The carbonates of potash, of soda, magnesia, lime, protoxide of iron, lead, (white lead,) zinc, and copper, are the principal.

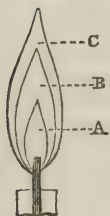
COMPOUNDS OF CARBON WITH HYDROGEN.—Light carburetted hydrogen,  $\text{CH}_4$ , is the common marsh gas, produced by the decay of vegetable matter under water. It is also the explosive gas (*fire damp*) of bituminous coal mines, and exists in the common gas used for lighting cities. It is colorless, light, so that it is employed in inflating balloons, and combustible, burning with a yellowish flame.

*Olefiant gas.*  $\text{C}_4\text{H}_4$ .—It is made by heating one part of alcohol with four of sulphuric acid, and separating the ether and oil of wine first generated, by passing the products first through a bottle containing solution of caustic potash, and secondly, through sulphuric acid. It is a colorless gas, with a slight unpleasant odor, sp. gr. 0.981, is very inflammable, and forms an explosive compound with oxygen. Its combustion is very bright, and it forms the most valuable constituent of common gas, and nearly the whole of oil gas.

The products of its perfect combustion are water and carbonic

acid; but, in a common flame, it is only at the outer surface that this result takes place. A flame may, indeed, be divided into three parts, a central, thin, non-luminous cone of unconsumed gas (A, Fig. 58); around this is a shell of partially burnt gas, and then the outer surface. The middle part is called the deoxydizing flame, B, and the exterior the oxydizing flame, C, in consequence of their action on bodies placed respectively in these positions.

Fig. 58.



Flame cannot pass through the close meshes of fine brass or copper wire; and on this principle Davy's safety lamp is constructed.

Mixed with chlorine, it forms an oily, ethereal liquid, of sweetish taste, called the *Dutch liquid*, or chloride of hydrocarbon. Burnt in an atmosphere of chlorine, olefiant gas becomes converted into hydrochloric acid, and a black deposit of carbon takes

place on the sides of the vessel.

*Coal gas* contains the two preceding gases, with numerous impurities, especially compounds of ammonia, sulphur, carbonic acid, and tarry bodies. Most of these are separated by condensation, and by passing the gas through a mixture of lime and water.

**CYANOGEN**—*Bicarburet of Nitrogen*.  $\text{HC}_2\text{Cy}$ ; eq. 26.0.—A gaseous body procured by heating the bicianide of mercury.

*Characters*.—A colorless gas, of an odor resembling peach blossoms, readily soluble in water, sp. gr. 1.806. It is converted into a liquid by a pressure of 3.6 atmospheres.

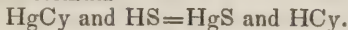
*Properties*.—It is irrespirable and inflammable, burning with a beautiful pink flame. A solution in water rapidly decomposes, yielding ammonia, hydrocyanic acid, a brown inert solid called *paracyanogen*, isomeric with cyanogen, and other bodies. This substance very closely resembles chlorine in its action, and is hence termed an electro-negative compound radical. Its symbol is Cy. Its compounds with the metals are termed cyanides.

*Compounds*.—With hydrogen it forms the cyanide of hydrogen,  $\text{HCy}$ , *hydrocyanic* or *prussic acid*. With oxygen it forms cyanic, fulminic, and cyanuric acids, which are isomeric. It also unites with iron, forming ferrocyanogen,  $\text{FeCy}_3$ , and ferridcyanogen,  $\text{Fe}_2\text{Cy}_6$ , and with sulphur forming another compound radical,  $\text{S}_2\text{Cy}$ , termed *sulphocyanogen*. Other compounds with cobalt, chlorine, &c., exist, which are of little interest. Of the cyanides of metals, the cyanide of potassium,  $\text{KCy}$ , is much employed to form the insoluble cyanides, in medicine, and in electro-galvanic plating and gilding. The cyanides of mercury, and of gold, have been partially introduced into medicine, but do not merit particular notice, being uncertain in their effects, and inferior to the corrosive sublimate for which they were introduced. The soluble cyanides



of potassium, sodium, and ammonium, are poisonous like prussic acid. The cyanide of silver is used to procure medicinal prussic acid. Cyanide of zinc, in doses of quarter of a grain to one grain, is said to act like medicinal prussic acid, and has been used as a substitute in the same diseases.

**HYDROCYANIC ACID—Cyanide of Hydrogen—Prussic Acid.** HCy; eq. 27.0.—This liquid is procured in the pure anhydrous state; by passing a stream of sulphuretted hydrogen over cyanide of mercury heated to redness, the sulphur of the gas unites with the metal, forming sulphuret of mercury, and the cyanogen and hydrogen combining, produce HCy, or hydrocyanic acid, which must be collected in a vessel refrigerated by ice; the reaction is represented in the formula



**Characters.**—This is a limpid fluid of great volatility, so that a drop exposed to the air, is partly solidified by the cold produced by the evaporation of a portion. It has a strong odor of peach blossoms, and is readily dissolved by water or alcohol. Its sp. gr. at 45° F., is 0.705, and it boils at 79° F. At zero, or —5° it is a crystalline solid.

**Properties.**—Cyanide of hydrogen has the same general properties, but in a feeble degree as hydrochloric acid. Its hydrogen is readily replaced by metals, and most of the cyanides can be formed by bringing to it a metallic oxide. It is indeed spontaneously decomposed, especially by the action of light, becoming resolved into an inert black substance called azulmic acid, and ammonia. It is a very feeble acid, scarcely reddening litmus, is not sour, nor able to decompose the carbonates. The vapor burns with a bluish flame. It is an intense poison, one drop having killed a dog in a few seconds of time.

**Tests.**—Cyanide of hydrogen, and the soluble cyanides, are precipitated of a white color, by solution of nitrate of silver. The precipitate does not dissolve in ammonia or cold nitric acid, but does so in the boiling acid. They are also known by adding a solution of potash, then a solution of old sulphate of iron, which contains both the protoxide and peroxide of the metal; by this means a greenish blue precipitate is formed which becomes of a rich blue (*Prussian blue*), by the addition of a little hydrochloric acid. The above procedure, without the final addition of acid, constitutes Messrs. Smith's antidote for this poison. It also serves as a means of recognizing the poison procured from the stomach, or matters vomited, of those who have died under its effects.

**In Poisoning.**—The smell will be a principal test, but this may arise from oil of bitter almonds, cherry laurel water, and other substances which do, however, gradually evolve hydrocyanic acid under certain circumstances. The matters yielding this

odor are to be cut up, if solid, and transferred to a glass retort, with water and sulphuric acid, and submitted to distillation over a water bath. The product is to be received in a refrigerator surrounded by ice, and if it contain hydrocyanic acid, it may be recognized by the odor and the foregoing tests.

The principal difficulty which arises in its detection is due to the minute portion which may produce a fatal result, and its great volatility, which causes it to pass off from the body in a few hours, unless very dilute.

*Uses.*—It is used in medicine, being a very valuable remedy as a nervous sedative, and to allay pulmonary and gastric irritation of nervous origin, as in certain forms of gastralgia and asthma. But for this purpose the foregoing anhydrous acid is not employed, nor kept, it being too prone to decomposition. A formula is given in the Pharmacopœias for a dilute acid which keeps much better; it is as follows:—Take 51 grains of cyanide of silver; 41 grains of strong hydrochloric acid, and a fluidounce of water. Add the salt to the dilute acid, shake and put aside in a dark place. This should be recent, and the dose is from one to ten drops, to be discontinued when headache or dimness of vision is produced; one drachm may be a poisonous dose. It acts both locally and by absorption; in the former case, it produces numbness, or destroys the sensibility of the nerves, and occasionally it produces vomiting and purging; but its chief action is, when absorbed, on the nervous centres, and especially the respiratory nerves.

In poisoning, convulsions, epilepsy, spasmodic breathing, dilated pupils, diminished pulse, sometimes almost reduced to nothing, occur when the dose is scarcely sufficient to produce death. Recovery occurs in such cases in half an hour, but it may be longer. The treatment is twofold, the nervous system is to be aroused by dashes of cold water over the chest, head and spine, and ammonia or its preparations given as nervous stimulants. Artificial respiration is also to be employed, and it is better to introduce a little chlorine into the air.

In addition to these, Messrs. Smith's antidote is to be given as soon as possible, as follows:—first administer solution of carbonate of potash, and follow it with a dilute solution of old sulphate of iron (containing the protoxide and peroxide); this destroys the hydrocyanic acid, and produces inert Prussian blue. Chlorine should be diffused in the air of the room, which is readily done by pouring some vinegar or other acid on common bleaching salt,—the chloride of lime or soda.

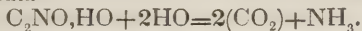
But unfortunately death is often produced in an almost imperceptible period of time; the unfortunate person falling as if instantaneously deprived of life, without struggle or convulsion, except, perhaps, a few gasping efforts of inspiration. The vapor

of hydrocyanic acid produces this result in minute quantities when inspired. In these cases, the establishment of artificial respiration with chlorinated air, constitutes the only chance of recovery.

The blood is often found dark, fluid, and having an oily appearance, and the muscles are occasionally insensible to the stimulus of electricity. There may also be engorgement of the lungs, brain and spinal marrow, with venous blood, but the arteries are empty.

**CYANOGEN WITH OXYGEN.**—Cyanogen produces three isomeric compounds with oxygen: *Cyanic acid*,  $\text{CyO}$ ; *Fulminic acid*,  $\text{Cy}_2\text{O}_2$ ; and *Cyanuric acid*,  $\text{Cy}_3\text{O}_3$ —of which the second has not been insulated, and the other two are only known in the hydrated state.

*Cyanic acid* ( $\text{CyO} + \text{HO}$ ) is obtained by distilling dry cyanuric acid; it is a colorless acid liquid, like acetic acid, blistering the skin. It is very instable, being converted by water into bicarbonate of ammonia



But it also spontaneously changes into an inert, white opaque solid, which is insoluble, but convertible by hot sulphuric acid into carbonate of ammonia, offering an extraordinary illustration of isomerism depending upon grouping, for the number of the atoms in this body are the same as in the acid.

Cyanic acid is peculiarly interesting, from its being one of the products of the changes taking place on animal food in the body. It exists in the urine in combination with ammonia, another substance produced by the same changes, these forming *Urea*, which is a hydrated cyanate of ammonia; its formula is  $\text{C}_2\text{H}_4\text{N}_2\text{O}_2$ , or  $\text{CyO} + \text{NH}_3 + \text{HO}$ . This body may also be obtained by artificial means, by the action of peroxide of manganese on ferrocyanide of potassium with heat, and the subsequent addition of sulphate of ammonia, &c. This salt is remarkably soluble, of a saline taste, and readily crystallizable into four-sided prisms.

*Fulminic Acid* exists in the fulminating powders of mercury, silver and other bodies. It has not been isolated, but is bibasic, and its compounds are remarkably instable.

*Cyanuric Acid* ( $\text{Cy}_3\text{O}_3 + 3\text{HO}$ ) is obtained by heating urea (cyanate of ammonia) which disengages ammonia; the residue is dissolved in hot sulphuric acid, and nitric acid added until the solution becomes colorless. On mixing with this product water, and cooling, crystals of the above acid fall. It is tribasic, little soluble, and distilled at a red heat yields hydrated cyanic acid only, being, as it were, split into three atoms.

**CYANOGEN WITH IRON.**—The two compounds, *Ferrocyanogen* or *Preussine* ( $\text{FeCy}_3$ ), and *Ferridcyanogen* ( $\text{Fe}_2\text{Cy}_6$ ), have not been isolated. They act precisely like electro-negative com-

pound radicals, and are so considered, the former being furnished with the symbol Cfy and the latter with Cfdy.

The crystalline substance called yellow prussiate of potash, is much used in the laboratory as a test, and also partially in medicine as a mild, nervous and arterial sedative. It is a compound of ferrocyanogen with potash, its formula being  $2K, Cfy + 3HO$ , and it is made on a large scale for the manufacture of Prussian blue, by heating to redness animal matters with potash and iron in iron retorts, washing out the salt and crystallizing. Prussian blue is obtained by adding a solution of this body to a solution of a peroxide of iron. This is not only used as a pigment, but as a substitute for cinchona in intermittent fevers, in doses of four to six grains, and in some neuralgias.

The red prussiate of potash, a beautiful salt, contains the ferridcyanogen; it also produces a variety of Prussian blue called Turnbull's blue, and is used as a test.

SULPHOCYANOGEN ( $S_2Cy$  or  $Csy$ ) has not been isolated, but its potash salt is made by heating powdered yellow prussiate of potash with half its weight of sulphur, and one third of carbonate of potash, and keeping them melted for a short time. Boiling water dissolves the *sulphocyanide of potassium*, which readily crystallizes. A solution strikes a blood red color with the per salts of iron, and is employed as a valuable test. This substance, in combination with ammonia and other bases exists, in the bodies of animals, and in human saliva.

CARBON WITH SULPHUR.—The *Bisulphuret of Carbon* ( $CS_2$ ) is made by adding pieces of sulphur to charcoal heated to redness in a porcelain tube, and receiving the vapors in a vessel containing water and ice. To obtain it pure, it is necessary to re-distill at a low temperature. It is a colorless, transparent, volatile liquid, possessed of great refractive and dispersing power, and was recommended by Brewster for the purpose of filling concave shells of glass to answer as lenses. Its specific gr. is 1.272, and it boils at  $108^\circ F$ . It volatilizes with so much rapidity as to produce great cold, but is of so offensive an odor that it can scarcely be employed. It dissolves sulphur and phosphorus.

## BORON AND SILICON.

*Symbol, B. Eq., 10.9.—Symbol, Si. Eq., 22.2.*

These two elements are closely connected, and have some affinity with carbon, but they are of little interest in medicine. *Boron*, from its strong affinity for oxygen, is little known; it is a greenish-brown powder, which, when heated, burns in the air into



*Boracic acid*,  $\text{BO}_3$ . This is found in some volcanic waters, and also in combination with soda, forming native borax, or *Biborate of Soda*.

The acid may be obtained from borax by adding sulphuric acid to a hot solution; on cooling, it falls in small crystalline scales. It melts at a red heat into a glass, and is a feeble acid at ordinary temperatures, but in a strong heat it is one of the most powerful. It was formerly thought to be a sedative, but is not now employed.

*Borax* is a biborate of soda; it is obtained in large prisms or octahedrons, by purifying the native salt. It is saline and cooling in taste, effloresces slightly in the air, and melts in its water of crystallization when heated. It is readily soluble, and has the composition  $\text{NaO} + \text{BO}_3 + 10\text{Aq}$ . It is used in the arts, and in the blowpipe analysis of the mineralogist. Its medicinal powers are also said to be considerable, for, according to Vogt, Dr. Copland and others, it throws the uterus into contractions, and may act as an abortive. It is also refrigerant and diuretic, and a large dose produces vomiting. Locally applied, it is a stimulant, and particularly useful as a detergent to aphthæ and ulcerations of the mouth and fauces. The dose internally is from half a drachm to a drachm.

*Silicon* is the basis of sand, rock crystal, and silicious matters generally. It is procured with difficulty, and resembles boron. Its chief compound is *Silicic acid*,  $\text{SiO}_3$ , which is sand or rock crystal. The salts of this body are nearly all insoluble, and make up a large portion of the earth's crust, especially the silicate of alumina which forms slate, and the varieties of clay; and the silicates of iron, lime, potash, &c. But by heating sand with four parts of carbonate of potash or soda, soluble silicates are obtained, from which the hydrated acid may be precipitated as a gelatinous substance by any acid. These salts exist in silicious springs.

Glass, porcelain, and common earthenware are silicates. Common table and flint glass contain a silicate of lead, and are unfitted for chemical purposes, from the lead being reduced by heat, and forming a stain like that of arsenic. Hard glass fitted for chemical vessels contains a silicate of lime and potash; it is very infusible and is not stained by heat.

Both boron and silicon combine with Fluorine, forming  $\text{BF}_3$  (fluoride of boron) and  $\text{SiF}_3$  (fluoride of silicon), which are gaseous.

## PART III.

### ORGANIC CHEMISTRY.

THE student having passed over the principal elements which make up organic bodies, is now prepared to enter upon their study. It is not our purpose, in this part, to take up every compound which the labors of its numerous cultivators have announced within the last few years, but only such as are useful in elucidating the functions of animals and plants, or are of medicinal interest.

Organic bodies are of two classes, either the immediate products of the functions of vegetables, as starch, sugar, fibrine, or of a subordinate importance, being produced by chemical changes impressed upon the former; the second class may be termed pseudo-organic. To this belong the acids, ammonia, cyanogen, the vegetable alkaloids, fatty bodies, ether, alcohol, &c. Many of these can be produced by artificial means from the first order, and represent a stage in the passage of organic matter into inorganic or mineral substances. Thus, by the oxydation of fibrine in the body, are formed urea, water and carbonic acid, and ultimately this complex body, which contains upwards of 1000 atoms, is reduced into water, carbonic acid, and ammonia, passing into inorganic matter. So sugar is changed into alcohol, then acetic acid, and finally into carbonic acid and water. The urea, alcohol, and acetic acid, are, in these instances, secondary or pseudo-organic bodies.

The true organic bodies, with few exceptions, are produced by plants only; they consist of carbon, hydrogen, oxygen and nitrogen chiefly; some, however, contain sulphur and phosphorus, whilst a few present traces of iron, potash, soda, lime, magnesia, and other bodies, either as an intimate ingredient, or as components necessary to the textures of which they form a part. Thus, it has been found that no cellules or tissue exist without saline matters, and usually with some of the above bodies. On the other hand, a numerous class contain only carbon, hydrogen, and oxygen; and some only carbon and hydrogen, as many essential oils. The number of atoms of each of the principal elements

is usually great, and this is one obvious reason for the instability of these compounds.

All organic bodies are decomposed by a red heat, and if burnt without access of air, nearly all yield charcoal. Many are changed at a less heat, whilst those which, like fibrine, albumen, casein, &c., contain hundreds of atoms, undergo spontaneous change or fermentation by exposure to oxygen and warmth. The fermentation of one body also communicates change to others, as in the action of yeast, which is decaying fibrine, on a solution of sugar. This catalytic action is not limited to organic compounds, but is a striking peculiarity in them. In nearly all these changes, the oxygen of the atmosphere appears to be the destroying principle, tending, in all cases, to produce inorganic compounds, of which carbonic acid ( $\text{CO}_2$ ), water ( $\text{HO}$ ), and nitric acid ( $\text{NO}_5$ ), are the chief; sulphuric and phosphoric acids are also the products of this agent on the sulphur and phosphorus of the organic world. When this oxydation is the principal feature of the decay, it is termed *eremacausis*, which means slow combustion.

The acids and alkalies often determine the products of decomposition; the former, producing substances which, like the oxide of ethyle, are basic; whilst the latter generate acids with which they combine. Nitric acid, by imparting its oxygen, is, however, a most potent agent in their decomposition, oxydizing them, and producing numerous pseudo-organic substances, usually of an acid reaction.

Until the last few years, little method existed in this part of chemistry. Each body was separated from the rest, and the ordinary laws of affinity were supposed to be at fault; but of late, it has been found that there exist groups or genera amongst organic bodies, which are often very extensive, and which seem to present a structure similar to those of the mineral world. There are not the simple metals and haloid bodies, but there are compounds distinguished by a striking electro-positive reaction, and others by an equally remarkable electro-negative affinity. These are both called compound radicals; but the terms electro-positive compound radical, and electro-negative compound radical, are more definite. So that the simple laws of the electro-chemical theory seem to hold for some of the most complex bodies in nature, ten, twenty, or hundreds of atoms, closely united, serving as a negative radical towards either a haloid body as oxygen, chlorine, bromine, or cyanogen, or towards a compound electro-negative radical.

By the discovery and extension of the theory of compound radicals, bodies formerly kept separate have been found closely connected, and the extraordinary changes occurring in their oxydation or fermentation, become clear and necessary results. A

new impetus has also been given to discovery, for no sooner is one of this class suspected than numerous researches are made with the more active agents to investigate the nature of its chlorine, bromine, cyanogen, &c., compounds. The following table contains most of the compound radicals at present admitted; many of them have not been isolated; but this is no argument against their existence, for the radical of nitric acid,  $\text{NO}_5$ , has never been separated.

TABLE OF COMPOUND RADICALS.

<i>Electro-positive.</i>	<i>Symbol.</i>	<i>Electro-negative.</i>	<i>Symbol.</i>
Benzyle	. Bz.	Cyanogen	. Cy.
Salicyle	. Sl.	Ferro cyanogen	. Cfy.
Cinnamyle	. Ci.	Ferrid cyanogen	. Cfly.
Ethyle	. Ae.	Cobalto cyanogen	. Ccoy.
Acetyle	. Ac.	Chromo-cyanogen	. Cely.
Cacodyle	. Cd.	Platino-cyanogen	. Cpty.
Methyle	. Me.	Iridio-cyanogen	. Ciry.
Formyle	. Fo.	Sulpho-cyanogen	. Csy.
Cetyle	. Ce.	Mellone	. Me.
Amyle	. Ayl.	Amidogene	. Am.
Lipyle	. Li.	Oxalyle	. Ox.
Allyle	. All.		
Proteine	. Pr.		
Uryle	. Ur.		
Acryle	. Acy.		
Margaryle	. Mgl.		

There are, however, many bodies not yet sufficiently examined for the detection of bases or radicals, as starch, gum, sugar, &c., which, however, present the characters of a natural group.

Isomerism is frequent and striking amongst organic compounds, and this will appear a necessary consequence of the grouping of so many atoms by a feeble force; hence, heat, light, or a catalytic action, often produces a new grouping with an entire change of properties.

Chemical and mechanical types also prevail in this class of bodies, (see p. 161,) and remarkable substitutions may frequently be made without their destruction.

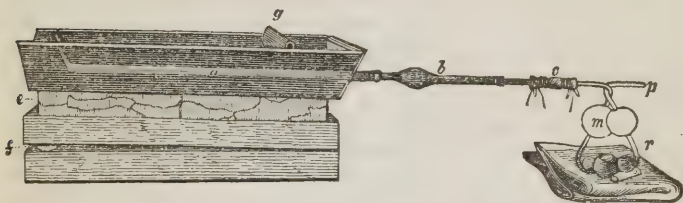
*The analysis* of organic bodies is rather complex, but the principle is sufficiently simple. The dry and pure body is mixed with several times its weight of pure, dry black oxide of copper, and heated in a tube of hard glass to a full red heat. By this means all its carbon and hydrogen, taking up the oxygen of the compound of copper, become converted into carbonic acid ( $\text{CO}_2$ ) and water. These are collected in separate weighed vessels; that for the water contains fused chloride of calcium, which has an intense affinity for the liquid, and retains all that enters it; by



re-weighing at the end of the operation, its amount is discovered. The carbonic acid is collected in a vessel containing a strong solution of potash, the weight of which, with the glass, is known—as all the gas which enters the solution is retained; by re-weighing at the close of the operation, its amount will be ascertained. By calculation, the amount of hydrogen and carbon in the water and carbonic acid is discovered, and also the quantity of oxygen consumed.

In this way the carbon, hydrogen and oxygen are ascertained, and if nitrogen be present, it may be collected over mercury as a gas, and its amount directly ascertained, or other means may be employed. The figure represents the apparatus for determining

Fig. 59.



the carbon, hydrogen and oxygen; *a* is the combustion tube set in a charcoal furnace *g*; *b* is the chloride of calcium or water tube; *c*, a connector of India rubber, and *m*, *r*, *p*, Liebig's apparatus of three bulbs to contain the solution of potash and retain the carbonic acid.

The above process is not difficult of execution, but requires nice manipulation. It is of no utility to the physician, and, therefore, not of sufficient importance to occupy the pages of a manual. Those who want to make themselves acquainted with the steps of the analysis will find longer articles in Graham's or Kane's chemistry.

#### ON THE PRODUCTION OF THE PRIMARY ORGANIC PRINCIPLES.

We cannot, by bringing the elements oxygen, carbon, and hydrogen in contact, cause them to unite in such a manner as to produce sugar or any other primary organic body. In such cases, if we employ heat or electricity as the arranging force, there are produced only the first binary compounds of the mineral kingdom. The secondary or pseudo-organic bodies may frequently be produced by certain chemical operations on the primary bodies, or by their partial destruction; but the latter are not generated either in the mineral world, or in the bodies of animals; they appear to

be the exclusive products of that tribe of the vegetable kingdom which are of a green color, and require light for their development.

The elements concerned in their production, are known to have allotropic states, but have not yet been insulated except in the  $\beta$  (*beta*) form; they have also an alpha or active state, which is surmised to be fluid, and it is in this, or perhaps some further condition in which they are thrown by the operation of the sun's light, that they combine to form organic bodies. These productions are therefore appropriately considered as the resultants of light, because that agent is essential to their formation, and the substances are totally different from such as would be produced by the operation of electricity or heat.

If we plant a seed in a soil perfectly fertile, but in the dark, a young plant is produced, which in a few days has attained its maximum size; here a suitable warmth, a proper soil, and active chemical or electrical conditions are present, but the seedling is of a pale yellow color (etiolated), it is surcharged with moisture, it has not the capacity to increase in size, and after a few days it dies. The nutriment stored up in the seed is converted by heat, moisture, and electrical action into a new arrangement, being partially decomposed—but the ability to group the fluid and saline matters of the soil, and the gases of the air, into new forms capable of supplying more aliment for its growth, and having the capacity of the nutriment of the seed, is absent. To accomplish this, light must be admitted, and if we allow its entrance on one side of a dark room, the young plant instinctively turns to it for succor and support.

In the dark, out of pre-existing starch, albumen and other primary organic principles, heat and the chemical force can produce the cellular tissue, oils, fats, resins, acids, alkaloids and other secondary bodies, by a new arrangement of the atoms of the former principles; but these forces are utterly powerless in the creation of starch and albumen out of water, carbonic acid and ammonia which constitute ninety-nine hundredths of the food of plants. We conceive, then, that the changes impressed by the vegetable on its products are peculiar, that their atoms are thrown into new and somewhat instable conditions, and unite by reason of it in groups more complex than in the mineral world, producing results altogether dissimilar, and being by this peculiar cause endowed more or less with the capacity of producing life, when consumed in an appropriate machine, as the body of an animal.

The true organic body is the result of the action of light, and its destruction for the production of inorganic matter is the effect of common electricity, or ordinary affinity. It is, therefore, in an instable state, and in its passage to that which is more perma-

nent, extraordinary phenomena arise, such as light, heat, electricity, and under peculiar circumstances, the motions which we term vital. At least, vital operations take place only during the change of organic matters, under the influence of electrical forces, and cease whenever these are arrested;—life being a resultant of innumerable chemical changes in the body, or in organized matter, derived from the action of plants, and ceasing as soon as a supply of the matter, or a stoppage to the changes, occurs. And these changes are of the nature of oxydation and the conversion of organic, back into mineral matter.

The plant, then, is the laboratory in which the true organic principles are created, and the sun's light the agent appointed to mould them into forms capable of sustaining the warmth and energy of animals. Of the agent we have said as much as is consistent with our limits, but it may be well to treat of the nature of the plant and the peculiarities of its action.

True plants are to be distinguished from mushrooms, or fungi, which possess functions entirely different, by their green color. They consist internally of cellules either of a hexagonal form or variously elongated for particular purposes. The leaf of a tree presents a specimen of a true plant, but the flowers have the functions of animals; they consume food, throw out heat, and frequently evince motion. The presence of tubes is not essential to the plant, these being provided for the purpose of allowing the fluids of the earth to pass up to the leaf; and another apparatus being also present in trees to carry the sap changed by the action of light, to the roots and other parts of the structure. But without entering into the discussion concerning the ascent and descent of the sap, and the difference of action between the leaves and flowers, it may suffice for us to produce the simplest instance of a true plant, and consider how it is nourished, and what changes are impressed upon its food by light.

The simplest vegetable, like the simplest animal, is a single cellule, called the *Chlorococcum vulgare*. It is found in large numbers on mouldy walls, exposed to the full action of light. Its form is spheroidal, and it consists of a perfect membrane united in all its parts; this is a fine colorless pellicle; in its interior is a green pulverulent matter, with water and other fluids and gases. Exteriorly, the bounding membrane touches the moist wall at one side and exposes itself to the sun at the other. Here is the entire plant, and the loftiest tree is but an aggregate of such cellules, its leaves possessing no other functions; they differ only in the arrangement of their parts.

The young plant is a translucent cellule, its bounding membrane is then hyaline, and it has no green matter in its interior. The membrane consists of *cellulose*, in combination with a little saline

matter ; it is the same as that of the cells of all other true plants. Cellulose is a substance almost identical with starch in chemical structure, and is procured from it as well as from sugar and other bodies by chemical changes, as in fermentation, germination and other kinds of sub-decomposition. Cotton, wool, and the hairy down of plants consist of the almost empty cells of cellulose. The chemical nature of this body is altogether different from that of the cell walls of animal substances ; these consist of compounds of albumen with saline matters.

The cell wall is everywhere complete, there being no fissures or punctures in it, but it nevertheless allows some bodies to pass through it to the interior, or is porous. Its porosity is not due to palpable apertures, for no microscope can discover them ; it is the porosity which belongs to all masses of matter, being due to the spaces which exist between the atoms. Hence it is to be distinguished in its effects from the action of holes which would allow leakage, for through these interstices such bodies alone pass as have an electrical or capillary attraction for the bounding membrane ; and such alone pass into the interior as have a similar relation to the fluid, solid or gases which may occupy it. That the cellules of plants have this interstitial or capillary porosity, I have directly proved by experiments with the epidermis of several species.\* The nature of capillary attraction, and the conditions necessary to the entrance of gases or fluids into the interior of cellules, will be fully examined in a subsequent chapter.

The cell lies, on one side, in apposition with the earth or moist wall on which it vegetates ; from this quarter it is supplied with water, holding in suspension carbonic acid, and a little ammonia, and containing saline matters, of which the phosphates and sulphates of potash, soda, lime and magnesia are the chief. Some plants, however, demand silica, iron, and other peculiar mineral bodies. The water, with the bodies it contains, is admitted by porosity into the plant, and serves by swelling it out, to advance its development. On the other side, the membrane is in contact with the air, from which it selects carbonic acid, and perhaps, in dry weather, a little carbonate of ammonia. It is now lighted by the sun, and the problem to be resolved is, what changes occur within this petty laboratory ? Such as are the foundation of life, such as shall hereafter furnish means for the support of the physical and mental activity of man himself !

The matters which have found entrance through the porous wall of the cellule, constitute the plant food, out of which all organic bodies are directly or indirectly to be generated. This

\* See my memoir, entitled "*The Physical Structure of Plants*," in the *American Journal of Science*. Vol. ii. 1846.



food, which alone serves to nourish the oak, the weed, or the mildew, consists of water, carbonic acid, ammonia, phosphoric and sulphuric acids, in combination with certain bases of potash, soda, lime and magnesia chiefly, these being in minute quantities, but absolutely essential. Put them together by the electrical force, and we have an impure solution of carbonate of ammonia, and to this they pass upon the final decay of the plant. The result of the chemical force is thus far uniform, but they are now to be grouped by the sun's light. Instead of a simple union in which oxygen gas is the most active element, as in chemical compounds; instead of a change the great feature of which is oxydation, the light commences organic operations by driving off the oxygen — by a procedure the reverse of that of electricity, and by deoxydation.

The yellow ray of light falling on the cellule distended by capillary action with food, commences its digestion by decomposing carbonic acid. This body,  $\text{CO}_2$ , loses its oxygen, most of which passes out of the cellule into the air, some of which is, however, retained; this decomposition is the effect of the sun's light, for it does not occur in the plant during darkness. Nascent carbon is thus produced, and it instantly unites with some of the water present, twelve atoms of carbon combining with ten atoms of water, whereby soluble starch or dextrine is formed, having the form  $\text{C}_{12}\text{H}_{10}\text{O}_{10}$ . Here is at one effort produced the most important body in organic chemistry. This gives a gummy consistence to the water of the cellule, which in the plant constitutes the elaborated sap. By another action of change the green color of the cellule is generated, and thereafter further alterations in the plant food occur. The green matter, termed *Chlorophyll*, serves the important purpose of decomposing the compound beam of white light; it absorbs the red and allows the yellow and some blue rays to pass during the vigor of the plant; but as soon as it acquires the orange and red tint of autumn, these active rays are more or less cut off, and the functions of the leaf are altered, or cease altogether.

This decomposition of carbonic acid is the starting point of life, and of the activity of the plant. The oxygen thrown off produces a gaseous current outwards, which is compensated by the substitution of a stream of fresh carbonic acid from the air; thus this important aliment is recruited. The thickening of the water by the dextrine, serves to solicit, on the other side, fresh supplies of fluid from the soil, and under the influence of these causes the cellule expands or grows. But chiefly is the effect remarkable in the chemical action of the gummy dextrine itself. The student will learn that sugar, starch, dextrine, cellulose and woody fibre are closely allied, all being compounds of carbon with water, nearly

in the same proportions, and being mutually convertible—they do indeed act as though they were almost isomeric. To have produced dextrine, is, therefore, the same thing as to have generated gum, sugar, &c., as these may be artificially made from it. But the dextrine is still more important, for by its combination with ammonia, present in the cell fluid, there is generated *proteine*; this process will be explained hereafter. *Proteine* is the basis or compound radical of fibrine, cheese, albumen, muscles and all the tissues of animals, and the essential component of all food capable of sustaining life. By this simple union, is therefore generated the most important product in nature.

But the deoxydizing action of the sunbeam is not confined to carbonic acid; the phosphoric and sulphuric acids present are reduced to their elementary forms. The sulphur and phosphorus uniting with *proteine* give it the structure of fibrine and albumen, and thus the process is completed, whereby the two great classes of organic bodies are produced.

To the first class, called the *Amylum* series, belong the non-azotized bodies, starch, sugar, gum, lignin, and their modifications. By oxydation these yield the vegetable acids, by deoxydation and fermentation they produce alcohol, ether, the oils and allied bodies, and by a high heat volatile and tarry substances.

The second class or the *Proteine* series contains albumen, fibrine, caseine, and their modifications in the blood and animal tissues; by the influence of chemical action these yield ammonia, urea, alloxan, and other secondary animal products, whilst in plants they seem to be connected with the production of the alkaloids and azotized coloring matters.

Subordinate to these groups of primary organic bodies, other substances are formed in the texture of plants; some of these are common to all, and many are peculiar to a few. They are, moreover, supposed to be produced by catalytic actions, occurring chiefly in the parts of plants removed from the sun's light, and in the roots where there is also a lower temperature than in the leaves. To this secondary class belong the oils and vegetable acids; the former are probably formed in the presence of light, for they are deoxydized, some containing no oxygen, and having a resemblance to the general formula  $C_5H_4$ . The oils are formed from bodies of the *amylum* series, for they can be produced by fermentation (*catalytic action*) from them; they also often appear in the Indian corn plant, as the sugar disappears, and are closely connected with its conversion, for carbonic acid is produced at the same time, and, as will appear hereafter, the separation of this body, with a few equivalents of oxygen, from the *amylum* compounds, converts them into oily and fatty bodies. As the acids are formed at the same time as the oils, the excess of

oxygen may serve to give them their necessary components, for the equivalents necessary to make up an atom of oil and of vegetable acid, represent two atoms of sugar, with a few atoms of carbonic acid which are separated.

The coloring matters of plants present a resemblance to the proteine bodies, usually contain a considerable amount of nitrogen, and are most probably secondary products of this radical. The vegetable alkaloids do not present this connection; they contain but little nitrogen, and appear to be formed by the action of ammonia on bodies of the amylum series.

In entering upon the field of organic chemistry, it may be proper to give some outline of our course. We propose first to present the primary bodies of the amylum series, then the derivatives from them produced by the action of fermentation, by oxydation and by heat; this will carry us through the greater part of the non-azotized organic bodies. Special chapters will be devoted to the oils and fats, alkaloids and coloring matters. The azotized group will next be presented; and we then enter on the subject of food, the process of digestion, the means by which chyle, lymph and the blood are borne through the system, with the nature of these fluids and their offices in the body, including respiration. The nature of secretion, especially of the liver and kidneys, will then be considered.

## THE AMYLUM SERIES, OR STARCH GROUP.

THE bodies of this series are not known to have any compound radical, but they all contain 12 atoms of carbon united to from eight to fourteen of water, and if we select  $C_{12}H_8O_8$ , which is lignin, for the primary body, the others will be hydrates of it. This body is also the most stable of the series, and one into which they are resolved in a great measure by plants. The principal bodies are enumerated in the following list, but they present several varieties, some of which have not yet been analyzed. Their formulas are doubled by a few chemists in consequence of some of them forming compounds with salt, &c., in the higher number. Those bodies placed in brackets are isomeric.

Starch	-	-	-	}	$C_{12}H_{10}O_{10}$
Dextrine	-	-	-		
Cellulose	-	-	-		
Tragacanthine	-	-	-		
Cane sugar	-	-	-	}	$C_{12}H_{11}O_{11}$
Gum Arabic	-	-	-		
Sugar of milk	-	-	-		$C_{12}H_{12}O_{12}$
Sugar of ergot	-	-	-		$C_{12}H_{13}O_{13}$
Grape sugar ( <i>glucose</i> )	-	-	-	}	$C_{12}H_{14}O_{14}$
Sugar of eucalyptus	-	-	-		
Sugar of starch	-	-	-		
Sugar of diabetes	-	-	-		
Lignin	-	-	-		$C_{12}H_8O_8$
Pectine	-	-	-		$C_{12}H_8O_{10}$

**STARCH—*Fecula*.**  $C_{12}H_{10}O_{10}$ .—It is found abundantly in the seeds of plants, and in the tubers, roots and other parts of annuals. It is separated for commercial purposes from wheat and potatoes; the process is as follows: The potatoes are rasped finely by a revolving instrument, and the magma thus produced is kneaded with a large amount of water frequently renewed, upon fine hair sieves, through which the water carries the starch, whilst the cellular and fibrous matters remain behind. The water is at first milky, but soon precipitates its starch, which is altogether insoluble in cold water, as an adhesive mass, which may now be dried at about  $212^\circ$ , and subsequently splits up into the columnar masses in which it is found in the shops. Potatoes furnish about 23 per cent. of starch, but wheat flour yields upwards of sixty, by a process very similar to the above.

The principal substances in commerce abounding in starch, are arrow-root, tapioca, sago, cassava, rice, barley, and grains gene-



rally; but the sweet potatoe, many fruits and vegetables, also contain large amounts.

Starch is tasteless and inodorous; it consists of white granules, having a regular organization, but differing in size in different plants. It is of soft texture, insoluble in cold water or alcohol, but soluble in boiling water, which appears to rupture the insoluble shell of the cellules, and allow the interior gelatinous body, called *amidine*, to pass out. The gelatinous starch dries into a yellow transparent body like gum, which afterwards swells in cold water. Starch baked at 400° F. has its cellules broken up, and becomes a clear brownish body called *British gum*, or *leicome*; it closely resembles common gum, and is used as a substitute in the arts.

A cold solution of starch (*amidine*) is gelatinous in proportion to its concentration; when dilute it is precipitated by solution of lime, baryta, oxide of lead, and other metallic bodies, as well as by alcohol—a few drops of tincture of iodine produce a rich blue color (*iodide of starch*), which is highly characteristic. This does not act in a boiling solution, and the color is destroyed by heating for some time, the iodine being volatilized. Starch is neutral, but compounds have been formed with oxide of lead, &c. By the action of dilute sulphuric acid and heat, or by *diastase*, starch is converted first into *dextrine*, and finally into starch sugar or glucose. This is a catalytic action, for a few drops of acid will change almost any amount into dextrine, which is isomeric with starch, and therefore consists of the same atoms differently grouped.

There are several varieties of starch—the chief of which are the gelatinous starch of Iceland moss, called lichen starch; carageenin or the starch of Irish moss; and *inuline*, which is derived from the root of the dahlia, Jerusalem artichoke, *Inula helenium*, and other bodies. Inuline is rendered yellow, and not blue, by iodine, and has the formula of  $C_{12}H_{11}O_{11}$ , according to Mr. Parnell.

Starch is used in the arts for the purpose of giving consistency and polish to textile fabrics; a solution serves also to give cardboard splints considerable hardness when dry. In medicine it is used as an absorbent to wounds; and in dietetics as a demulcent when cooked. Rice, and the bodies already enumerated, consist chiefly of this principle, and are used to an injurious extent in the sick chamber, under a false impression that they are highly nutritious, and easy of digestion. So far from this, it has been found that these aliments are very injurious in cases where there is irritation of the gastro-enteric membrane, especially in children; for, by collecting about the follicles, the granules irritate them, producing or increasing diarrhœa. Indeed, in the *Hôpital des Enfants Trouvés*, of Paris, it has been found that the diet of rice, to which children suffering from diarrhœa had been condemned,

was one of the chief causes of mortality in that institution, and light jellies have now been substituted. In these cases it produced follicular inflammation of the intestines, which was the cause of death. The barley-water and farinaceous slops of our sick rooms are equally pernicious, and should be cast aside as a relict of the exploded systems which prescribed indiscriminate purgation, bleeding and sweating as the sheet anchors of the healing art. Iodide of starch has been recommended as a medicine, but possesses little of the activity of iodine, and becomes uncertain in its composition if kept, or exposed to warmth.

**SUGAR.**—Under this name are grouped a variety of bodies, having a sweet taste, and solubility in water, as their characteristics. The principal are cane sugar, glucose, and milk sugar, or lactine, but there are also a sugar of ergot, a sugar of the Eucalyptus, and a variety derived from manna and mushrooms, called *mannite*, which has the formula  $C_6H_7O_6$ ; this is crystalline and non-fermentable.

*Cane Sugar—Ordinary Sugar.*—In the crystallized state its formula is  $C_{12}H_{22}O_{11}$ , but two atoms of the water appear to be attached as water of crystallization, and removable by heat, when it melts, and forms the yellowish, transparent *barley-sugar*.

It is obtained from the juice of the sugar cane, beet root, and sugar maple, for commercial purposes, but exists in many other plants. The clear juice is first inspissated by boiling, the scum being continually removed; when it has acquired a certain thickness, it is placed in shallow pans to granulate or crystallize. It is then drained from the uncrystallizable syrup or molasses, and constitutes raw or Muscovado sugar. This is further refined by redissolving, heating with the serum of blood or white of eggs, and removing the scum. The syrup is next filtered through animal charcoal, which decolorizes it, and, being inspissated again to the crystallizing point, it is put into conical moulds. This forms, when dried by a stove, common loaf sugar, which may be further refined by pouring through it in the mould, before drying, some clear syrup. When carefully prepared from syrup, it crystallizes in the fine, large, oblique rhombic crystals of sugar candy. Sugar is deprived of water by a high heat, and resolved into a brown body called *caramel*, used as a coloring matter.

Sugar is neutral in properties, but it forms compounds with common salt, the oxides of lead, barium, calcium, &c. By dilute sulphuric acid it is first converted into glucose, but by long heating it throws down black precipitates called *sachulmine* and *sachulmic* acid, nearly resembling common ulmine, the product of the slow decay of woody matter. By the action of caseine ferment it is converted into lactic acid. The test will be given under Glucose.

*Glucose*;  $C_{12}H_{14}O_{14}$ .—*Fruit Sugar, Grape Sugar, Starch Sugar, Sugar of Honey, Sugar of Diabetes*.—As its name implies, it abounds chiefly in fruits, and is readily procured from raisins or honey; it is also the sugar found in the urine of persons afflicted with *diabetes mellitus*. Cane sugar, starch and lignin are readily converted into it by the action of very dilute sulphuric acid, assisted by heat in the case of the two latter. It is less sweet and soluble than cane sugar, and crystallizes with difficulty into confused masses. By heat it loses four atoms of water, blackens and becomes decomposed; it is also blackened by a solution of caustic potash which does not affect cane sugar. On the other hand, it dissolves freely in strong sulphuric acid, and forms *sulphosaccharic acid*, which yields regular salts with bases. Cane sugar is decomposed and blackened by the strong sulphuric acid. Heated with the alkaline earths, glucose forms *glucic acid*, and with a boiling solution of the alkalies, the *melasinic acid*—bodies of no peculiar interest.

The principal distinction between glucose and the other sugars is that it is readily fermentable, whilst they have to be converted into it before taking on this change, and some do not ferment under any circumstances—as mannite, and glycyrrhizine, or the sugar of liquorice. It is also distinguished from cane sugar by its action on the oxide of copper. If glucose and cane sugar be mixed in separate tubes with a very dilute solution of sulphate of copper, and a solution of caustic potash be then added until the precipitate first formed is re-dissolved, beautiful blue solutions will be obtained in both vessels; but if they be now heated, the one containing glucose will rapidly change to an opaque green color, then orange, and finally yield a dark red precipitate, leaving the fluid clear; but the fluid containing the cane sugar will remain blue for a long time before it throws down a red precipitate of suboxide of copper. This test is employed also for the purpose of detecting sugar in diabetic urine, the only additional step being the separation of any precipitate which may fall on the introduction of the solution of potash. This is called *Trommer's test*, and is highly satisfactory.

*Sugar of Milk, Lactine*— $C_{12}H_{12}O_{12}$ —is present in milk, and obtained by evaporating whey to a syrup, and allowing the sugar to crystallize. It forms white four-sided prisms of considerable hardness, is sparingly soluble, and does not readily ferment, and is converted into lactic acid by caseine ferment. It is used by the homœopaths to mix with their medicines.

*Sugar of Diabetes Insipidus*.—This curious substance, derived from the urine of persons suffering from insipid diabetes, has all the chemical characters of sugar, but is tasteless.

**GUM.**—Under this head are grouped a number of bodies which

are more or less acted on by cold water—some, like arabine and dextrine, being very soluble, and forming a thick mucilage; others, like tragacanthine, merely swelling. They are nearly all tasteless, and when dry, form a more or less transparent, brittle or horny mass, without crystalline form. The chief varieties are dextrine, arabine, tragacanthine and pectine.

*Dextrine*.—This is the mucilaginous fluid of vegetables; it is also produced by the action of very dilute sulphuric acid and other catalytic agents on solution of starch, and in germination. Its name is derived from the property a solution possesses of turning a ray of polarized light to the right, whereas gum turns it to the left. It is the great cytoblastema of plants, out of which the various tissues are made by cell growth. It is produced from the starch of seeds and buds by *diastase*; which is a true ferment derived from the oxydation of albumen. The seed contains albumen or fibrine and starch; so long as these are kept dry, no change occurs, but on committing it to the soil, moisture and warmth act, and oxygen is absorbed the last, acting on the proteine body, produces *diastase*, and this communicates a change, catalytically, to the starch, which hence becomes a solution of dextrine, and fitted to supply the materials of growth to the cell germs (cytoblasts) of the embryo. Its formula in the dry state is  $C_{12}H_{10}O_{10}$ .

*Arabine—Gum Arabic*;  $C_{12}H_{11}O_{11}$ .—It is the produce of several trees, of the genus *Acacia*, being thrown out as an exudation from their trunks. The purest is without color, bright, readily soluble, forming a thick mucilage with water. It is employed as a demulcent, and to suspend oily and resinous bodies in pharmacy. Alcohol and a solution of subacetate of lead precipitate it from its solution.

*Tragacanthine, Cerasin, Bassorine*, and several other gummy bodies, refuse to dissolve in cold water, but swell and become pulpy.

*Pectine—Vegetable Jelly*.—This substance is found in some fruits, and in the carrot and similar roots; it is sparingly soluble in cold water, but dissolves by heat and gelatinizes as it cools. It is tasteless, and abundant in the currant. By contact with the alkalis it is changed into *pectic acid*, a substance apparently isomeric with pectine. Its composition is not quite certain, but according to Mulder is  $C_{12}H_8O_{10}$ .

*LIGNIN*.—This name is given to the interior insoluble and fixed matter of woody fibre. The fibre itself consists of fusiform cells arranged in bundles, the material of which, like all the cells of the plant, is *cellulose* ( $C_{12}H_{10}O_{10}$ ), and these contain the lignin, the structure of which is  $C_{12}H_8O_8$ . Fine linen offers a beautiful illustration of cellular lignin; it is white, tough, tasteless, insoluble and innutritious. Strong sulphuric acid converts



it in the cold into a tough mass resembling a solution of dextrine; but if the mixture be warmed, the lignin will be charred. If the solution of dextrine obtained in this way be boiled, it becomes converted into a solution of grape sugar, which may be depurated by neutralizing the acid by chalk, filtering and evaporating to dryness. Linen rags may thus be made to yield more than their weight of grape sugar.

Cotton fibre presents us with a specimen of nearly pure cellulose, and there is not much distinction between the reactions of this body and linen. They have the same general properties; they may both be made into a magma by beating with water, from which preparation paper is made by spreading it over wire frames by rollers. They both dissolve in cold sulphuric acid into dextrine, and they both yield a detonating compound with nitric acid, called gun cotton.

*Gun Cotton, Nitric Cellulose, Pyroxyline.*—When cotton or linen is immersed in a mixture of equal parts of concentrated nitric and sulphuric acids, their texture is scarcely affected, but they combine with two atoms of nitric acid, and when carefully washed and dried at a low heat (130° F.), become more explosive than gunpowder. It may be exploded by heat at about 200° F., and by the blow of a hammer. This body was introduced by Professor Schonbein as a substitute for gunpowder, but it is too dangerous to be much employed.

*The Pseudo-organic Bodies derived from the Amylum Series.*—The foregoing bodies of the starch group are readily changed into pseudo-organic substances, but with unequal facility. The long-continued action of the alkalies and alkaline earths causes several to become altered into acids, as in the production of the glucic and melasinic acids from glucose. Sulphuric acid more completely disorganizes many of the series, but its compounds are not of great interest.

It is to the action of oxydation that we are indebted for most of these changes. This may be rapid and complete, as when nitric acid is made to act upon starch, sugar, &c., or it may be slow, as in the production of acetic acid from alcohol; in this instance, it is termed *eremacausis*, or slow combustion.

Fermentation and catalytic action are other important means of change. This kind of action is most influential on solutions of glucose; but starch, lactine and other bodies are influenced by it, and highly important bodies result from its action, as alcohol, ether, lactic, acetic and butyric acids.

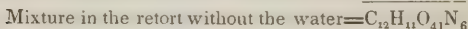
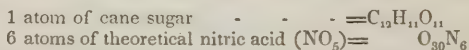
We shall in the following pages confine ourselves to the above sources of change, and adduce the principal products of their action.

## THE ACTION OF DIRECT OXYDATION ON THE AMYLUM SERIES.

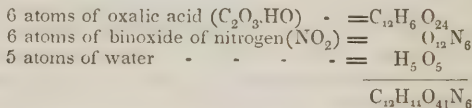
All the principal bodies of this series except some of the gums and lactine, are converted into oxalic acid by the action of nitric acid. Gum and sugar of milk yield mucic acid by the same agent. The strength of the acid also influences the process, for the saccharic or oxalhydric acid is produced when dilute nitric acid acts on sugar.

**OXALIC ACID.**—Formula of the true acid  $\text{HO} + \text{C}_2\text{O}_3$  of the crystallized acid  $\text{HO} + \text{C}_2\text{O}_3 + 2\text{Aq}$ . To prepare this body take one part of sugar, five of nitric acid of sp. gr. 1.42, diluted with twice its weight of water, place in a retort and warm gently. Much effervescence occurs with the evolution of red fumes, which indicate the decomposition of the acid and oxydation of the sugar. When the action slackens, heat is again applied, and the superfluous acid is distilled off, until the liquid of the retort deposits crystals on cooling. These are drained, redissolved in a little hot water, and set aside to crystallize.

The explanation of the changes is sufficiently simple.



This is resolved into



So that one atom of sugar, deriving eighteen atoms of oxygen from the decomposition of the nitric acid, yields six atoms of oxalic acid. But in practice the changes are not so simple, for some further decompositions occur.

Oxalic acid is white, intensely sour, more soluble in hot than cold water, and is usually found crystallized in oblique rhombic crystals. These are at a gentle heat deprived of their two atoms of water of crystallization, and then form a white powder which may be sublimed; but if the ordinary acid be strongly heated, it is decomposed into formic acid, carbonic acid and carbonic oxide without solid residue. It is a powerful acid, the basic HO being replaced by most metallic oxides.

It is an active poison, and is occasionally taken by mistake for

Epsom salts, and being abundantly used in the arts for cleaning metals, it may be procured for felonious purposes with facility. In large doses, it acts as a corrosive poison, disorganizing the stomach, but when dilute, it diminishes the heart's action, and acts also on the nervous centres. The antidote, which is to be at once employed, without recourse to emetics or the stomach pump, is pounded chalk mixed up with water. This forms the inert oxalate of lime. The inflammation of the stomach and other symptoms are to be met by the ordinary remedial means, care being taken not to increase by active depletion, the debility of the system too much.

Oxalic acid is not now used in medicine; but in dilute doses it is refrigerant, and an arterial sedative; its taste is intensely sour, and it has, therefore, to be mixed with a good deal of water.

It is readily recognized in solution or in its soluble salts by producing a white precipitate with lime water, and it is employed for detecting this base in the laboratory. The precipitate of oxalate of lime is soluble in nitric acid. When heated in the open air, it turns black, and is converted into carbonate of lime, or, at a higher temperature in a closed vessel, into caustic lime. The acid is also decomposed by heat. Warmed with strong sulphuric acid, it becomes resolved into water, carbonic acid and carbonic oxide.

*Compounds.*—The *oxalates of potash*, especially the binoxalate, occur in many plants, as the sorrel and docks. The quadroxalate, which is very sour, is sometimes employed to remove ink stains. The *oxalate of ammonia* is found in some organic substances which are undergoing decay, as guano, and employed in solution as a test of lime. It is a crystalline body of some solubility, and remarkable for the production of *oxamide* when heated. The salt of ammonia yields several gaseous bodies, and finally a dense white smoke, which may be sublimed, and is the oxamide. This contains the elements of amidogene with two equivalents of carbonic oxide, or  $H_2N + 2(CO)$ , and represents a small class of bodies containing amidogene.

*The Oxalate of Lime.*—This salt has the composition  $CaO, C_2O_3 + 2HO$ , and it is formed whenever oxalic acid acts on a solution of lime. It exists in many lichens and plants, as the rhubarb; and forms one variety of urinary calculus, the mulberry calculus. It is insoluble in water, but dissolves in nitric acid, and is decomposed by heat, being converted first into the carbonate of lime, and subsequently into caustic lime in a closed vessel. By this means the mulberry calculus is readily distinguished as well as by its rough reddish-brown color.

Numerous other oxalates have been formed, but they have been put to no use.

**SACCHARIC ACID**—*Oxalhydryc Acid*,  $C_{12}H_5O_{11} + 5(HO)$ .—This is formed by the action of dilute nitric acid on sugar. It is crystalline, very soluble, sour, and forms soluble salts with lime and baryta, and an insoluble salt with lead. When mixed with solution of nitrate of silver, it yields no precipitate, but on adding ammonia, a white body falls, which is decomposed by gently warming the vessel, and metallic silver is precipitated, which, adhering to the glass, gives it a bright mirror-like appearance. This acid is pentabasic, but its compounds are scarcely known.

**MUCIC ACID**;  $C_{12}H_8O_{14} + 2(HO)$ .—This acid is procured by heating gum or sugar of milk with pretty strong nitric acid. It is bibasic, a white, sparingly soluble body of a slightly sour taste; its salts are little known. By heat it is converted into the volatile *Pyromucic acid*.

**OTHER BODIES**.—The *Suberic acid*, obtained by the action of nitric acid on the ligneous matter of cork, is very similar to the mucic, but more soluble; its formula is  $C_8H_6O_3 + HO$ . *Xyloidine* ( $C_6H_4O_4, NO_5$ ) is produced by the action of nitric acid sp. gr. 1.5 on starch, which yields a gelatinous body that forms with water a white insoluble substance. Paper dipped for a moment into the acid, and afterwards washed in water, assumes a parchment-like appearance and great inflammability. This is another form of xyloidine. The gun cotton is a direct compound of cellulose with nitric acid, and has been already described in the article on Cellulose.

## OF FERMENTATION.

THE word fermentation was originally employed to indicate the movement taking place in wort, when subject to the action of leaven or yeast, but has been greatly extended in its meaning, and now includes several cases of decomposition or change of a catalytic nature, taking place in the bodies of the amylum series, and especially in glucose, and under the influence of a ferment. The ferment consists in every case of a proteinous body, which is in the state of incipient decay, probably suffering oxydation by the access of atmospheric air.

Temperature has great influence over this process; thus it will scarcely occur at  $40^\circ F.$ , and the resulting body depends considerably on the degree of heat maintained during the action; thus at  $50^\circ$  caseine in milk produces lactic acid by fermentation, but at  $80^\circ$  it engenders alcohol, and if carbonate of lime be present, a third substance called butyric acid is formed.

The degree of decomposition of the ferment is another important cause of change in the product; thus oxydized albumen, acting as a ferment, converts starch into sugar, and produces the organic



action by which cellulose is formed; when further changed, it converts this sugar (glucose) into lactic acid, and still changing further, at length produces alcohol from the sugar. Thus three or four products arise from the action of the same ferment, which is, however, itself undergoing change, and may be regarded not as one, but as many ferments. That it is the ferment which continues the action, appears from the fact that a given amount of ferment will only produce a determined change in sugar or other bodies; but it has the capacity of affecting a large amount. Thus one part of *diastase*, which is a peculiar ferment produced in the germination of seeds and growth of buds, is capable of converting 2000 parts of starch into sugar.

In some kinds of fermentation, as in the brewing of beer, fresh portions of ferment are formed out of proteine bodies present in the wort, so that a double action occurs; the sugar is changed into alcohol, carbonic acid and water, by one atom of yeast, but the albumen present in the wort is also changed, and forms a new proportion of ferment. But nothing of the kind occurs if we add a given weight of yeast to a pure solution of sugar; in this case, there being no albumen to become changed, the first yeast passes through a series of changes, and is finally destroyed, disappearing from the fluid and only affecting a determinate amount of saccharine matter.

This distinction is important, for it furnishes us with an explanation of the different results which attend the action of the same ferment on different solutions, and it has also been employed by Liebig in his theory of the action of certain contagious poisons. His views are plausible, and worthy of some attention on the part of the profession. Among the contagious poisons adduced, are the small-pox, vaccinia, plague, frambæsia, syphilis, dissection virus, measles, scarlet fever, the froth of the mad dog, &c. In all these cases, something called the virus (ferment) is made to act on the body; it may be inhaled by the air, or immediate contact of the ferment may be necessary. This finding its way into the system, produces changes similar to those hereafter to be described, and is also attended by the production of further amounts of the virus, which is formed like new yeast in wort, in consequence of the presence of some suitable proteinous body. This new ferment (*virus*) may be used in several of the above cases to reproduce the disease in other persons. Another peculiarity exists with respect to the action of some of the above poisons—they act on the body, in most cases only once, as in small-pox, vaccinia, scarlet fever, measles. In these, Liebig supposes that the matter susceptible of change is destroyed in the body on the first attack, and not again engendered. But these are rare in comparison with those cases in which the ferment acts every time it is introduced into the body,

as in syphilis, plague, the dissection virus. Here there is not a peculiar body influenced, but the ordinary principles of the system. Again, there is a class of diseases which originate in the action of a ferment (*virus*), but which do not reproduce it—such are bilious remittent, intermittent fevers and similar endemics.

It has long been an interesting question to discover *the method in which the ferments act*. They obviously do not act by any direct affinity, for the yeast added to a solution of sugar, neither unites with it nor with the alcohol produced. If we investigate the matter more closely, we find that the yeast forms no chemical union whatever with the products of decomposition; that it has no affinity to satisfy, and is itself undergoing decay. Berzelius includes the action of fermentation among the cases of *catalysis*, in which the result produced differs from those of common chemical affinity, and in which the active agent either remains unaffected, *acting by its presence*, or does not enter into union with the products.

To this kind of action are also referred the cases where dilute sulphuric acid acting on a solution of starch, converts it into glucose without being affected itself, and numerous changes induced by spongy platinum, platinum black, and other porous media on compound bodies. Many of these cases offer merely illustrations of the fact that, when gaseous bodies are presented to one another, or to liquids in a very condensed state, union occurs, the platinum, &c., acting physically or by capillary attraction to condense. Thus, oxygen and hydrogen are made to unite by spongy platinum, because this substance condenses them so powerfully that they are presented to one another in such a form that the resistance offered to their union by elasticity is overcome. So platinum black, by condensing the oxygen of the air, and bringing it in contact with the vapor of alcohol, oxydizes that body, converting it into acetic acid and water. In some cases of catalytic action, the mere act of condensation may be sufficient to produce chemical change, but this does not occur in many instances, and it is also to be remembered that the fact of such powerful condensation argues the presence of a considerable force.

Another view of the action of fermentation, which also includes other cases of catalysis, is to the effect that the ferment or other active body disturbs the electrical equilibrium of the bodies present, or polarizes their particles, and thus sets up new chemical actions. We know that union between atoms is effected by the electrical force, and that decomposition results whenever a new electrical state is produced; and it may be urged in favor of this view, that the action of fermentation is capable of producing changes out of the fluid in which it is occurring, which are analogous to those of electricity—thus it will cause a mixture of oxygen and hydrogen to unite, and other similar effects.

Liebig is the author of a third hypothesis, to the effect that the ferment being in a state of decay, molecular movements are transpiring in its substance, which are communicated to circumjacent bodies of an instable composition. In this view of the case, the cause and effect are molecular movements, and the action of fermentation is separated from catalytic actions generally. Prof. Hare objects to this doctrine, on the ground that it is incredible that one molecule of diastase undergoing a slight movement should impart a similar motion to two thousand of starch without being at all checked itself.

It may be well to observe that the theory which attributes the effects of fermentation and catalytic actions generally to the influence of electrical disturbance, is that most consonant with the present views of chemists.

*The results of fermentation are very different.* When the ferment is but slightly changed, as in the case of diastase, the pepsin of gastric juice, the ptyalin of saliva, it produces little more than a new grouping of the atoms. Thus diastase converts starch into glucose and cellulose, which scarcely differ in composition. So ptyalin converts sugar into lactic acid which is isomeric. Pepsin renders insoluble albumen, and fibrine soluble. These are all cases of change in grouping;—there is nothing evolved.

But the action of yeast is widely different, for it changes the sugar of the wort into alcohol, water and carbonic acid, which are substances in no way similar to the sugar. Hence, the same proteine body, in different stages of decay, constitutes different ferments, and as it departs more and more widely from the constitution of proteine, the more power has it to decompose the fermentable matters on which it acts. The tendency of fermentation is, moreover, similar to that of all other actions on organic bodies—to reduce them to the inorganic state, the final products being water, carbonic acid, ammonia and cyanogen. But it does not act so rapidly as heat or nitric acid, and produces a great number of intervening changes.

Any substances which have the power of hindering the decay of the ferment, as metallic salts, many spices, alcohol and similar bodies, also stop fermentation. These are termed antiseptics, and the chief are corrosive sublimate, creosote, pyroxalic spirit, sulphate of copper. Salt and other bodies act by removing the water from the compound. Heat and cold are also antiseptics; the first acts by evaporating the water and hindering that freedom of motion which is essential to chemical change—whilst cold, by solidifying the water, accomplishes the same end. The absence of oxygen, by which the proteine body is first changed, also renders fermentation impossible.

From the foregoing, the student will be prepared to understand

that there are many kinds of fermentation, or catalytic action, produced by the presence of a ferment. The chief of these are:

1. The organic fermentation.
2. The germinative fermentation.
3. The viscous fermentation.
4. The lactic acid fermentation.
5. The butyric acid fermentation.
6. The vinous fermentation.

1. THE ORGANIC FERMENTATION.—We propose this name for that kind of change which occurs in the solutions of the organic acids and their salts, in mucilage of gum, or paste and other organic bodies in contact with a moderate amount of water. For its manifestation, a temperature from  $50^{\circ}$  to  $80^{\circ}$  appears to be most suitable; and, as in all other cases, the presence of a ferment containing azote but in the first degree of change. Oxygen is also necessary to its commencement, but the quantity may be extremely small. The chief product of this action is cellulose, which will be found in cells aggregated together in various ways, forming threads in the *saccharomyces* or *torulæ*, and fleecy masses in the *mycoderms*, of which the mother of vinegar is an instance. The varieties of mildew and mould belong to this class of organized products, the existence of which is dependent on the first step of decomposition in the *amylum* or *proteine* series. Mulder has determined that yeast consists of an organized body, the cells of which contain an oxide of *proteine*, which continually undergoes change and escapes from the enclosure.

In every case of organic fermentation, azotized matter is present, for if we make a solution of an organic salt in fresh distilled water, taking every precaution that no nitrogen be present, there will appear no mould or *mycoderm*. Nearly any azotized body will serve to originate this change; fibres of silk will do so, and other bodies which appear to be little acted on themselves.

It is probable that the action under consideration is the cause of cell development in all cases; for why should the dextrine of the plant or the albumen of the blood assume the configuration of cells? There must be for this effect some competent cause, and we can conceive of none so probable as that under consideration. According to this view, when albumen assumes the cellular figure, as it does in yeast and the bodies of animals, there are certain conditions of moisture, temperature and oxygen present constraining it; otherwise it would remain inorganized—there is a change of grouping perfectly analogous to that of starch into sugar, or starch into dextrine.

Whilst the organic fermentation appears to act by re-arranging the molecules of organic matter, and forming similar or isomeric compounds, it does not seem to be so restricted in its action as



many other kinds of fermentation. In nearly every case, particularly in the germinative, viscous and vinous fermentations, there are produced organized bodies; these it is presumed result from the first action of the ferment, or express the first alteration in the ferment itself. As the vinous fermentation comes to an end, the *torulæ* become shrivelled and finally subside in the liquid.

*Torulæ*, the doubtful objects called vibriones, and a genus called *sarcinia*, have been found in the diseased gastric juice and urine of man. The first two of these consist of cellules, arranged linearly, the last of four cuboidal cells arranged together.

From what has been said, it will be understood that these organized products may be more or less permanent or extremely transient. When the ferment is in minute amount and the action on an organic salt, as citrate or tartrate of potash in solution, the cellular product remains unchanged for months; but in other cases, as in the vinous fermentation, this is a stage in the changes and not a final result.

**2. THE GERMINATIVE FERMENTATION.** *Germination.*—The changes which occur in the seed under the influence of warmth, moisture and oxygen, constitute a true fermentation, not peculiar to the seed but of common occurrence. It takes place in what has been called the panary fermentation, and according to Bouchardat, occurs in the stomachs of dyspeptics and those laboring under diabetes mellitus. It is characterized by the production of glucose and cellulose from starch, or, in other words, in germination there are two actions of fermentation, the one producing the conversion of starch, and the other being analogous to the organic fermentation.

The temperature most congenial, ranges between 60° and 100° F., the presence of oxygen is indispensable, and water must be supplied in moderate quantities. The chemical phenomena are the absorption of oxygen and water by the seed or fermenting body, the evolution of carbonic acid and heat, and the production of sugar (*glucose*), cellulose, and a particular ferment termed *diastase*. The seed, it will be remembered, contains starch and albumen, from which latter the diastase is produced by the action of oxygen. A reference to the bodies of the *amylum* series shows that the action of the ferment is little more than to form a new grouping of the atoms of starch.

The malting of barley offers an illustration of the germinative fermentation on a large scale. The seed becomes sweet thereby, and throws out a leaf formed of the cellulose engendered by the ferment, and it contains diastase which may be separated in an impure state. It is a white soluble body, resembling the gluten

of flour. It is capable in the separate state of acting on a solution of starch, and converts it into dextrine and glucose, so that it is an independent ferment. It is not, however, a fixed body when moisture is present, for if malted barley be not dried at a considerable temperature, the diastase undergoing further change converts the sugar into lactic acid, or it becomes a lactic acid ferment.

Diastase not only causes germination in seeds, but it also determines the growth of buds, and probably all growth in the vegetable kingdom. According to Payen and Persoz, it is found deposited about the eyes of the potato when the tuber is beginning to germinate.

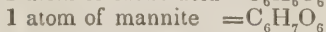
Mialhe has found a ferment having the characters of diastase in the saliva, being the white substance precipitable by alcohol and formerly called *ptyalin*. It is an oxydized proteinous body, and has the property of converting a solution of starch into glucose. He calls it diastase. Leuchs had previously observed that saliva has the property of converting starch into sugar. There is but  $\frac{2}{100}$ ths per cent. of diastase in saliva, but it will be remembered that this ferment is extremely active, one part changing two thousand of starch.

Bouchardat announces the existence of diastase in the stomach in diabetes, and infers that the sugar (*glucose*) of the urine and blood in that disease arises from its action on the starch of the food. Hence abstinence from amylaceous substances constitutes a principal feature of the treatment, and has been found to answer well. But Barreswil has found that the property of converting starch is also possessed by the *pancreatic* secretion and the *gastric* juice, and that in all these cases the effect only takes place when the ferments are in contact with alkaline matters, or possess an alkaline reaction in consequence of the presence of the tribasic phosphate of soda ( $\text{Na}_3\text{PO}_4, 2\text{NaO}$ ); for if either the saliva, gastric juice or pancreatic secretion be acidulated, they lose this property but become solvents of albumen and fibrine. This view of the case awakens a suspicion that *pepsin* or the ferment of the gastric juice is also diastase, or a proteinous body of a very analogous character. For the further consideration of this subject, the student is referred to the article on digestion.

**3. THE VISCOUS FERMENTATION.**—Vegetable juices, as that of the beet, which contain much sugar when kept at the temperature of  $86^\circ$  to  $104^\circ$  F., undergo fermentation from the changes occurring in the albumen they contain. But under the circumstances prescribed, there is formed mannite, lactic acid, and a viscid body said to be identical with gum arabic, whilst a little carbonic acid and hydrogen are evolved. There is no alcohol produced, and from the thickening of the fluid, this is distinguished

by the name of the viscous fermentation. It can be established in a solution of pure sugar by the action of a ferment prepared by boiling yeast in water, filtering and using the fluid portion.

The changes here are those attributable to a new order of grouping chiefly, for the gum produced belongs to the amylum series. The mannite is a variety of sugar, and the lactic acid is isomeric with milk sugar. Thus one atom of sugar, by the viscous fermentation, is split up into



The sum represents an atom of glucose, minus one atom of water, and one of oxygen. There are various other means of originating the viscous fermentation, as by animal membranes. The changes in the preparation of sauerkraut also belong to this species of fermentation. In some portions of France they prepare hay by a similar process.

4. LACTIC ACID FERMENTATION.—In the preceding case lactic acid is formed, but in many instances it is generated as the sole or principal product of fermentation; this is especially true in the souring of milk at moderate temperatures ( $50^\circ$  to  $70^\circ$  F.). In this change, the proteine body of milk (*caseine*) first undergoes a slight decomposition, which may be detected by the altered taste, and acting as a ferment, splits up the atom of lactine into two of acid,  $\text{C}_{12}\text{H}_{12}\text{O}_{12}$ , becoming  $2(\text{C}_6\text{H}_6\text{O}_6)$ , so that this is another case of the re-arrangement of the molecules of the sugar present.

This result is also brought about in milk by animal matters, the stomach, or any portion of the mucous membrane of the calf, dog, pig, &c., steeped in water for several days, changes not only milk but solutions of sugar and starch. A solution made from the salted and dried mucous membrane of the calf, called *rennet*, effects the same result. Diastase kept moist for several days, becoming changed into a new ferment, also brings about the lactic fermentation.

This is a very important change, inasmuch as lactic acid is found in nearly every part of the bodies of animals, and food containing it already formed, appears to be easy of digestion, highly nutritious, and especially serviceable in the fattening of animals. To this end it is the custom of some farmers to feed hogs and oxen with a slightly acid mash, which is found to contain this acid.

The action of the mucous lining of the stomach on starchy matters, indicates that lactic acid is produced in digestion, and that the lactic fermentation forms a stage in that important process.

This acid has been found in the stomach, perspired fluid, the muscular juice, the urine, and in most parts of the body.

*Lactic acid* may be obtained for examination and pharmaceutical purposes, by adding sugar of milk to sour milk, and allowing the lactic fermentation to proceed, occasionally neutralizing the acid formed by carbonate of soda. When the transformation is supposed to be complete, the mixture is boiled to coagulate the caseine and then filtered; the filtrate being evaporated at a low heat to the consistence of a syrup, alcohol at  $100^{\circ}$  F. is next digested on this, and dissolves out the lactate of soda. This alcoholic solution is next decomposed by sulphuric acid, the sulphate of soda falls, and there remains lactic acid dissolved in the alcohol.

Concentrated by cautious evaporation, it forms a thick colorless fluid, sp. gr. 1.215, without smell, and intensely sour. It is very soluble in water, and alcohol, and is a strong acid, uniting with most basic oxides to form lactates. It is monobasic, its formula being  $\text{HO}, \text{C}_6\text{H}_5\text{O}_5$ , the HO being replaced by oxides. The acid is pretty permanent, non-volatile, but it is decomposed at a temperature of  $482^{\circ}$  F., being resolved into a crystalline body, having the formula  $\text{C}_6\text{H}_4\text{O}_4$ , with acid properties, and into water and other substances. At a red heat the lactates are converted into carbonates.

The *lactates* of potash and soda are deliquescent. The lactate of lime is insoluble, and found in *nux vomica*. The lactate of protoxide of iron is a mild chalybeate, recently introduced into medicine. Lactic acid itself, in the dilute state, has been recommended in atonic dyspepsia, at meals, as a promoter of digestion and as a tonic.

**5. THE BUTYRIC ACID FERMENTATION.**—This is one of the most interesting of the changes produced by ferments, because, in it, an oil is generated from sugar and bodies of the amylum series, and thus great light is thrown on the digestion of this kind of food. It has been decided by the experiments of Liebig, Dumas, Bous-saingault, Edwards, and Payen, that amylaceous matters become converted into fats during digestion; but the process was utterly unintelligible until the discovery of the butyric acid fermentation by M. Pelouze.

It is effected by exposing the washed curd of milk (*caseine*) to a strong solution of sugar, mixed with chalk, at  $80^{\circ}$  F. The caseine becomes a ferment by decay, producing the characteristic changes of a viscous and lactic acid ferment, and finally generates butyric acid, which, uniting with the lime of the chalk, forms butyrate of lime—hydrogen and carbonic acid gases are also liberated. An atom of glucose by this fermentation yields an atom of butyric acid, 4 of carbonic acid, 2 of water, and 6 of hydrogen, or:



1 atom of glucose	-	-	-	-	$C_{12} H_{14} O_{14}$
yields					
1 atom of butyric acid	-	-			$C_8 H_8 O_4$
4 atoms of carbonic acid	-	-			$C_4 H_2 O_8$
2 atoms of water	-	-	-		$H_2 O_2$
4 atoms of hydrogen	-	-	-		$H_4$
					<hr/>
					$C_{12} H_{14} O_{11}$

Butyric acid is found in butter, being the acid of the flavoring substance called *butyrin*, which is butyrate of oxide of lipyle. It has also been detected by Drs. Ragsky and Percy in fecal matters, by Berzelius in urine, by Gmelin in the juices of the stomach and sweat, and by Lehmann in the kiestein of the urine of pregnant females.

It is, therefore, a fat belonging to the system of animals, and its presence in milk leads us to infer, that if this can be produced by fermentation, other fats may be formed from amylaceous bodies in digestion, especially as lactic acid is resolved into it, and probably other fats.

*Butyric Acid.*—The acid is obtained by decomposing the butyrate of lime formed in the above process, by sulphuric acid; or it may be obtained in minute quantities from butter. It is an oily, slightly yellow fluid, with the odor of rancid butter, and is very soluble in water, alcohol, and ether. Its sp. gr. is 0.963, it is volatile, and boils at 327° F. It is of a caustic, acrid taste, corrodes the skin, and the vapor is inflammable. It does not solidify by a cold of 4° F.

It forms numerous salts, butyrates, the most interesting of which is that with oxide of lipyle, which is butyrin, a component of butter. Chevreul found that this body could be produced artificially by uniting butyric acid with oxide of glycerine, and that a fat very similar to butter was the product. Fibrine, in its decomposition, also yields butyric acid, and it appears to be formed by the action of potash at 320° F. on this body. It is, therefore, a product of the changes (*metamorphoses*) of both amylaceous and proteinous bodies.

6. THE VINOUS FERMENTATION.—In this case decomposition takes place in the saccharine matter (*glucose*), and it is resolved into alcohol, which is a pseudo-organic body,—carbonic acid, and water, neither of which are organic. To produce it, the ferment is more advanced in decay than in the preceding cases, being in the state of yeast. The temperature at which it takes place is about 70° in saccharine juices, wort, must, or a solution of sugar, but in milk it does not occur under 80° F. Water is also essential; indeed, the proteine body could not form yeast without heat and moisture. Oxygen is also necessary to this change.

It has been found that fibrine and albumen in the moist state

have the property of absorbing oxygen from the air. By this oxydation there are first formed oxides of proteine, which combine with water; but if it be pushed farther, the fibrine or albumen becomes disorganized, forming ammonia, carbonic acid, and extractive matters as final results, with the evolution of sulphuretted hydrogen and other gases. This constitutes the *putrefactive decay*, or the final destruction of the proteine body. Liebig attributes this proneness to decay to the instability of the nitrogen, and it is true that the most azotized bodies readily suffer decomposition whether organic or inorganic, but the primary action is the property of these bodies to absorb oxygen. In other cases it may be due to the affinity of hydrogen and nitrogen, as in the decomposition of hydrated cyanate of ammonia or urea, and in the explosive fulminates.

Mulder has determined that yeast is an oxide of proteine and that it is in the last stage before decomposition. It exists in the form of isolated cellules, the enveloping membrane of which is *cellulose*, the interior a proteine body, the composition of which is  $C_{40}H_{37}N_5O_{26} = Pr + O_8 + 6(HO)$ . This undergoes further decay, but the stage at which it produces the vinous fermentation is now reached.

To form alcohol and the other products, it is necessary that the sugar should be in the state of glucose. The changes are, as follows:

1 atom of glucose	.	.	.	.	$C_{12} H_{14} O_{14}$
yields					<hr/>
2 atoms of alcohol ( $C_4H_6O_2$ )	-	-			$C_8 H_{12} O_4$
4 atoms of carbonic acid	-	-			$C_4 O_8$
2 atoms of water	-	-	-	-	$H_2 O_2$
					<hr/>
					$C_{12} H_{14} O_{14}$

In this change the elements of the yeast do not participate although it is undergoing change at the same time, and finally becomes exhausted, having only a limited capacity to produce fermentation. The alcohol produced in this change is one of an important group of bodies which contain the hypothetical radical ethyle, and will be examined under that head.

The vinous fermentation is most common in saccharine fluids, but it may be established in milk. It does not belong to that class of fermentations which occur in living plants or animals, but is destructive in its action. In the case of diabetic urine it has been proposed to test the presence of sugar, especially of the insipid variety (*diabetes insipidus*), by fermentation, adding yeast and looking for the evolution of carbonic acid and the production of the cellular objects called *torulæ* which cause fermenting fluids to become ropy. But Trommer's test is much more satisfactory. (See *Glucose*.)

A fermentation very similar to the vinous takes place in urine,

the urea of which is converted into carbonic acid and ammonia under the influence of a ferment formed by the decay of a small amount of mucus (oxydized proteine) voided with it. If the mucus be separated the urea remains unchanged, if it is allowed to absorb oxygen and is moist; this substance is changed, as follows:

1 atom of urea	-	-	-	-	C <sub>2</sub>	H <sub>4</sub>	N <sub>2</sub>	O <sub>2</sub>
6 atoms of water	-	-	-	-	H <sub>6</sub>			O <sub>6</sub>
yield					<hr/>			
2 atoms of ammonia	-	-	-		H <sub>6</sub>		N <sub>2</sub>	
2 atoms of carbonic acid	-	-			C <sub>2</sub>		O <sub>4</sub>	
4 atoms of water	-	-	-		H <sub>4</sub>		O <sub>4</sub>	
					<hr/>			
					C <sub>2</sub>	H <sub>10</sub>	N <sub>2</sub>	O <sub>8</sub>

Uric acid and other organic bodies rich in nitrogen are decomposed in the same way, the products being almost, if not quite, inorganic.

Hence the fermentation may produce mere change in grouping, the products being of a more stable kind, without evolution of gas—this occurs in the bodies of animals and in plants. Or there may be formed pseudo-organic bodies, as lactic acid and alcohol; this also may occur in plants and animals. Lastly, it may entirely disorganize, producing carbonic acid, water and ammonia, from the most organized substances: this does not occur in animals, except in cases of disease. In disease it does occur, for we have urine voided, containing carbonate of ammonia obviously derived from a change in the urea. If the matter were more closely investigated, there is little doubt it would be found that many pathic fluids and products arise from fermentation. In the results of fermentation we perceive a gradual return of the complex organic body, by various graduations, all of which may occur in the same solution, to the inorganic state; the various products serving only as temporary stopping places.

### EREMACAUISIS.

The formation of vinegar in wines and beer was formerly attributed to a peculiar fermentation, and called the acetous. But it has nothing to do with fermentation being produced not by the action of a ferment, but by the slow absorption of oxygen. In this and analogous cases, of which there are a great number, Liebig calls the process *Eremacausis*, or slow combustion, the absorption of oxygen being as essentially a feature of it as in ordinary combustion. By this means organic bodies become oxydized and further approximated to inorganic substances.

The conditions necessary are the continuous presence of oxygen,

a limited amount of moisture and a variable temperature. The results will depend upon the supply of oxygen, the temperature and the body subject to change; when the action is rapid, heat is always thrown out.

Both azotized and non-azotized bodies are subject to eremacausis. Familiar illustrations of this action are afforded in the formation of vinegar from alcoholic fluids, in the rotting of wood in a moist situation, in the production of nitrates from ammonia in heaps of manure, and in the functions of the human body. The continual introduction of oxygen by respiration, the evolution of oxides, as carbonic acid, water and cyanic acid show that the bodies of animals are the scene of a constant eremacausis by which the fats, muscles and tissues are constantly metamorphosed into effete matters. The function of digestion is, however, a process of fermentation.

In eremacausis it is not necessary that there be a ferment, but it is essential that there be a means of absorbing and supplying oxygen. This, in the case of the production of vinegar (*acetic acid*) from beer and wine, is accomplished by the action of the fluid, or it may be accomplished by a piece of platinum; for, if the vapor of alcohol pass over platinum, it becomes oxydized, and forms acetic acid. In the bodies of animals the fibrine of the blood is the substance which absorbs and supplies the oxygen, and the albumen of the serum also does so. Charcoal, the varieties of platinum, fibrine, and other bodies act in these cases *catalytically*, not being themselves necessarily changed, but yielding oxygen in the active (*alpha*) state to any instable body. But the decomposing body may absorb the gas itself without the intervention of any agent, and the case is not the less one of eremacausis.

The oxydation of pseudo-organic bodies, especially alcohol, wood spirit and potatoe spirit, lead to the production of important bodies, and it is an action always resorted to for the purpose of investigating organic bodies. The common means of doing so is, to pass a stream of the vapor over spongy platinum.

Heat may also be regarded as an exciting agent of this kind of action, when the organic substances are exposed to the air, from which they derive their oxygen. In these cases, the body may be split into two or more by a new grouping and oxydation, or it may be almost destroyed.

We are now prepared to consider the disorganizing effects of fermentation, eremacausis and heat on the amyllum series.



## ALCOHOL AND ITS DERIVATIVES.

## THE COMPOUNDS OF ETHYLE.

ALCOHOL—*Spirit of Wine; Hydrated Oxide of Ethyle* ( $C_4H_6O_2$ ) is procured by the action of yeast, or fermenting animal matter, on a saccharine solution. One atom of glucose yields two of alcohol, and carbonic acid and water are separated, thus:

1 atom of glucose	-	-	-	-	$C_{12} H_{14} O_{14}$
yields					
2 atoms alcohol ( $C_4H_6O_2$ )	-	-	-	-	$C_8 H_{12} O_4$
4 atoms carbonic acid	-	-	-	-	$C_4 O_8$
2 atoms water	-	-	-	-	$H_2 O_2$
					<hr/>
					$C_{12} H_{14} O_{14}$

In this change the ferment does not participate by its elements, but the solution becomes thick, and there are produced in it cryptogamic plants, consisting of strings of cellules, the bounding wall of which is cellulose—these are termed *Torulæ* and *Saccharomyces*. The alcohol is separated by distillation.

*Characters.*—Alcohol is a transparent, colorless liquid, of a vinous smell, hot taste, and sp. gr., at  $60^\circ F.$ , 0.793 when pure, boils at  $173^\circ F.$  It has never been frozen. That in commerce contains about 12 per cent. of water and some corn oil, which impairs the odor. The pure anhydrous, or absolute alcohol, is obtained by treating rectified alcohol with carbonate of potash or caustic lime, and redistilling about three-fourths off at a low temperature. The dilute or proof spirit (*Spiritus tenuior*) contains about 50 per cent. of alcohol.

*Properties.*—It is highly inflammable, burning with a hot, pale flame, much used in the arts from being free from smoke. By this combustion it is resolved into water and carbonic acid, oxygen being absorbed from the air. It has remarkable solvent properties, dissolving many saline bodies, the resins, essential oils, castor oil, the alkalies, most acids, and many vegetable principles, but it does not dissolve the fats, fixed oils (except castor oil), or saline bodies insoluble in water, or which effloresce in the air. With some saline bodies it unites, like water does in its hydrates; such compounds are termed alcohates by Graham. It is freely soluble in water and ether, indeed its affinity for water is so considerable that it acts as an antiseptic, preserving animal matters by removing the water necessary to establish fermentation in them.

Chemically considered, alcohol exhibits all the properties of a hydrated oxide, and if strong acids be brought in contact with it,

assisted by a moderate heat, they separate the water and enter into combination with the oxide, forming sulphates, oxalates, &c. The base here is termed *ethyle*; it has not been insulated, but we know its oxide, which is ether, and numerous compounds, and they all point to the existence of a powerful electro-positive radical, capable of forming haloid compounds and oxygen salts. The composition of ethyle is inferred to be  $C_4H_5$ , and the following are its chief compounds:

*The Ethyle Series.*

Ethyle, symbol Ae	-	-	$C_4H_5$
Oxide of ethyle	-	-	$Ae_2O$
Chloride of ethyle	-	-	$Ae_2Cl$
Iodide of ethyle	-	-	$Ae_2I$
Hydrate of the oxide	-	-	$AeO+HO$
Bisulphate of ethyle	-	-	$Ae_2O+2(SO_3)$
Phosphate of ethyle	-	-	$Ae_2O+PO_5$
Hyponitrite of ethyle	-	-	$Ae_2O+NO_3$

&c. &c. &c.

Of the foregoing bodies, several are of medical interest and will be considered; others, as the iodide with the bromide, sulphide, cyanide of ethyle, are not put to any use. Of the compounds of oxide of ethyle, the acetate, carbonate, oxalate, formate, butyrate and numerous others, are merely objects of curiosity. The *enanthic ether* forms the bouquet of wines; other compounds with vegetable acids have odors resembling those of the apple, melon and other fruits, so that it is highly probable that these are due to ethereal bodies.

*Uses and Effects of Alcohol.*—It is used as a solvent in the arts, for its hot flame, and for the production of the ethers. In medicine it is an arterial stimulus in small doses, and serves well in cases of debility to arouse the powers of the system, but is transitory in its action. It acts as a local stimulant, and also enters the blood, having been detected in that fluid and in urine; in the circulation it is speedily oxydized, becoming converted into carbonic acid and water. The effect of its change in large quantities is to produce stupor, and in fatal cases complete asphyxia. These results are due to the separation of the oxygen of arterial blood, which acquires a venous color, and consequently the loss of that vital stimulant on the brain and muscular apparatus. Respiration therefore becomes labored, the countenance bloated, the lungs and other parts of the system engorged with venous blood, and hence death from a true asphyxia. We should, therefore, in cases of alarming drunkenness, employ artificial respiration as our sheet anchor, the contents of the stomach and bowels being removed by the stomach pump

and enemata. In this case an admixture of protoxide of nitrogen with the air may be serviceable; as well as the interrupted current of galvanism to keep up the motion of the respiratory muscles.

The poisoning produced by the long-continued use of ardent spirits, one symptom of which is delirium tremens, seems to arise from a direct action of alcohol on the stomach and nervous centres. It is not to be overlooked by the student of medicine, that the administration of medicines in the form of tincture, or the employment of spirituous potions in convalescence, may awaken a taste for alcohol leading to pernicious habits.

The spirituous beverages in use contain different proportions of alcohol, the amount being in brandy, rum and whisky from 50 to 60 per cent.; in tinctures about 40; in the strong wines, as madeira, port, sherry, malaga, from 21 to 30; in hock, champagne, claret, sauterne and the lighter wines, from 11 to 16 per cent.; in ale, cider and stout 7 to 8.50; in draught porter about 4 per cent.

**ETHER—Sulphuric Ether; Oxide of Ethyle;  $\text{AeO}$ .**—Ether is produced by any means which will separate the atom of water from alcohol, or will convert  $\text{AeO}, \text{HO}$  into  $\text{AeO}$  and water. It was formerly done by distilling dilute sulphovinic acid, which is prepared by warming equal weights of sulphuric acid and alcohol; this forms a sour syrupy liquid, having the composition  $\text{AeO}, 2\text{SO}_3 + \text{HO}$ . If this acid be diluted with water, so that its boiling point be from  $260^\circ$  to  $310^\circ$  F. and distilled, ether and a little water pass over and there remains in the retort hydrated sulphuric acid.

But this is an uncertain and expensive process, for below  $260^\circ$  alcohol distills over, and above  $310^\circ$  olefiant gas and other bodies pass over. To obviate these difficulties the *continuous process* has been introduced, in which a stream of alcohol is made to enter the still gradually, so that the boiling point of the mixture is retained at about  $300^\circ$  F., and in this way a small quantity of sulphuric acid serves for the change of a large amount of alcohol. There pass over the vapors of ether and water, which are condensed in a Liebig's or other condenser, the two fluids separating spontaneously in the receiver.

**Characters.**—It is a limpid, colorless fluid, of a peculiar and penetrating odor, hot taste, sp. gr. at  $60^\circ$  0.720, boiling at  $96^\circ$  F. It has not been frozen, is extremely volatile, slightly soluble in water, but very soluble in alcohol.

**Properties.**—It is highly inflammable, burning in contact with oxygen into water and carbonic acid. It is a solvent of many fats, oils and vegetable principles, and has all the properties of a metallic oxide, forming compounds with most acids. The vapor forms an explosive mixture with air, and when in contact with it some time is changed into acetic acid by oxydation.

*Uses.*—It is employed in organic analysis as a solvent; and in medicine, being a diffusible stimulus and antispasmodic, and has been found, when inhaled, to destroy sensibility for a time so completely as to allow of the performance of severe surgical operations. The soporific effect is similar to that of alcohol, but produced more rapidly, and it does not cause so much local irritation. The ether entering the blood becomes oxydized, removing the oxygen destined to the metamorphoses of the tissues; hence venous congestion and a partial asphyxia occur. Where its action has been excessive, the same means are to be employed for the restoration of the patient as in the case of drunkenness.

In the inhalation, two drachms or more of ether, washed free from alcohol by water, are put on a small sponge, which may be put in a vessel perforated by several holes, and placed over the mouth and nose. The patient inhales through this, each draught of air carrying a large amount of ethereal vapor. Stupefaction occurs in two or more minutes, and lasts five or more minutes.

*Etherization* has been freely practised with little danger, but in cases of hemoptysis it is not safe. There are also irritable states of the brain and spinal centres, in which it is counter-indicated. Chloric ether, or the chloride of ethyle, and chloroform have the same property, and the latter has been freely employed; it is more active, thirty to fifty drops producing insensibility in the space of one to two and-a-half minutes; but it appears to be frequently followed by considerable prostration. The therapeutical action is the same, except that the chlorine of these compounds becomes converted into muriatic acid in the blood, and seems to produce the debilitating effects complained of. It would appear that parturition is accomplished much more favorably under the influence of chloroform than of ether. Its action on the system is more rapid but less persistent, and in consequence of the subsequent prostration, ether is now supposed to be preferable, for the patient recovers from its effects much more completely.

**HALOID COMPOUNDS OF ETHYLE.**—The *chloride of ethyle* or hydrochloric ether ( $\text{AeCl}$ ), is made by saturating alcohol with hydrochloric acid gas, distilling at a low heat, washing the vapor with water, and condensing in an iced refrigeratory. It is highly volatile, limpid, colorless, of a pleasant aroma, sp. gr. 0.874, and boils at  $84^{\circ}$  F. It has the properties of ether, but is more active; it has been recommended as an anæsthetic agent, but is probably inferior to ether. As an antispasmodic it has been employed in asthma and adynamic diseases of the nervous system, but is not better than ether; the dose is  $\text{f}\text{ʒss}$ . *Cyanide of ethyle*—hydrocyanic ether, ( $\text{AeCy}$ ) has been recommended by Majendie, in whooping-cough, asthma and convulsive diseases, as a nervous sedative; the dose is five to ten drops, but it is rarely employed,



in consequence of its insufferable odor; it is also an active poison. The *iodide*, *bromide* and *sulphide* of ethyle are not employed.

**SALTS OF OXIDE OF ETHYLE.**—Oxide of ethyle ( $\text{AeO}$ ) unites with most acids, and the quasi-salts thus formed are ethereal, volatile, and act as diffusible stimulants. There is a great number of these compounds, but the hyponitrite and acetate are the only ones used in medicine. These ethers are nearly all decomposed by caustic potash and other alkalies, which are, therefore, incompatible.

The *hyponitrite of oxide of ethyle; nitrous ether* ( $\text{AeO}, \text{NO}_3$ ) is employed in an impure form in medicine, being dissolved in alcohol in the spiritus ætheris nitrici. It is a pale yellow, volatile liquid, having an agreeable odor of apples; its density is 0.947, and it boils at  $62^\circ \text{F}$ . It is employed, dissolved in alcohol, in medicine as an antispasmodic and diuretic. *Acetate of oxide of ethyle; acetic ether* ( $\text{AeO}, \text{C}_4\text{H}_3\text{O}_3$ ) is made by heating, in a retort, three parts of acetate of potash, three of alcohol, and two of sulphuric acid, washing the vapor with water, digesting the refrigerated ether with chalk, and afterwards with chloride of calcium and rectifying. It is a highly fragrant, limpid liquid, has a density of 0.890, and boils at  $165^\circ$ . It is a little employed in medicine in the same way as common ether.

**COMPOUNDS CONNECTED WITH ETHYLE.**—*Sulphovinic acid* has already been referred to, in the formation of ether. Its composition is  $\text{AeO}, 2\text{SO}_3 + \text{HO}$ , and it would appear to be a hydrated bisulphate of oxide of ethyle, but it has none of the properties of the ethers, being an acid capable of combining with metallic oxides and forming *sulphovicates*. Its salts are soluble, and all suffer decomposition by heat, as does the acid itself. There is also a *phosphovinic acid*, ( $\text{AeO}, \text{PO}_5 + 2\text{HO}$ .) and an *oxalovinic acid* ( $\text{AeO}, 2(\text{C}_2\text{O}_3) + \text{HO}$ .) having similar properties.

*Heavy oil of wine; Oleum æthereum*, formerly used as an antispasmodic, when pure is a sulphate of oxide of ethyle and sulphate of etherole ( $\text{C}_4\text{H}_4$ ), a body isomeric with olefiant gas. It is produced by distilling dry sulphovinate of lime; when the heavy oil and alcohol pass over, the latter may be separated by water. It is a yellowish green, oily body with a powerful odor somewhat resembling that of peppermint.

*Olefiant gas* ( $\text{C}_4\text{H}_4$ ) is obtained by heating dilute sulphovinic acid above  $320^\circ \text{F}$ . This acts as a true basic compound radical, forming three chlorides, a bromide, iodide, &c. These bodies resemble the ethers, so that, according to some authors, alcohol and the compounds of ethyle, may be reduced to compounds of olefiant gas. Thus, then, is established an intimate relation between all the foregoing bodies and the oils, which are chiefly reducible by heat into olefiant gas.

The chloride of olefant gas ( $C_4H_4Cl_2$ ) is the oil of the Dutch chemists, and may be made by mixing equal volumes of chlorine and olefant gas. It is a colorless, fragrant liquid, boiling at  $180^\circ$  F. In this substance is observed the most striking illustration of substitutions and the doctrine of types, the whole of the hydrogen being removable by chlorine without altering the number of atoms. The products are as follows :

1 Dutch liquid	-	-	-	-	$C_4H_4Cl_2$
2 Terchloride of acetylene	-	-	-	-	$C_4H_3Cl_3$
3 " "	-	-	-	-	$C_4H_2Cl_4$
4 " "	-	-	-	-	$C_4HCl_5$
5 Perchloride of carbon	-	-	-	-	$C_4Cl_6$

Many other bodies produced by the action of chlorine, sulphur and similar agents on alcohol, ether, olefant gas and their compounds, are known to chemists, but are not employed in medicine or the arts.

#### COMPOUNDS OF ACETYLE.

When alcohol is slowly oxydized, or subjected to eremacausis, acetic acid is produced; this is found to be a hydrated oxide of a hypothetical basic radical of which there are several compounds known; these are included in the adjoined table :

Acetylene, symbol Ac	-	-	-	-	$C_4H_3$
Hydrated oxide of acetylene ( <i>Aldehyde</i> )	-	-	-	-	$Ac_2O + HO$
Acetylous acid ( <i>Aldehydic Acid</i> )	-	-	-	-	$AcO_2 + HO$
Acetic acid	-	-	-	-	$ACO_3 + HO$
Terchloride of acetylene	-	-	-	-	$Ac_2Cl_3$

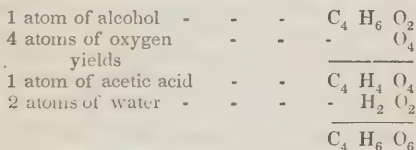
*Hydrated Oxide of Acetylene; Aldehyde* has the same relation to acetylene that alcohol has to ethylene. It is an alcoholic fluid of a suffocating odor, sp. gr. 0.79, boiling point  $72^\circ$  F. It undergoes slow eremacausis in the air, or under the influence of platinum black, becoming converted into acetic acid.

*Acetylous Acid* is a peculiarly acrid volatile body and is obtained in an impure state by placing a piece of spongy platinum heated to redness in the vapor of ether; the platinum continues incandescent for a long time and an acrid vapor is produced formerly called lampic acid and containing the acetylous acid. This arrangement constitutes Davy's aphlogistic lamp.

*Acetal* is a colorless aromatic liquid containing the elements of ether and aldehyde ( $C_4H_9O_3$ ); it is procured by a troublesome process from the result of the action of moist platinum black on the vapor of alcohol.

**ACETIC ACID—Pyroligneous Acid; the Acid of Vinegar** ( $C_4H_3O_3 + HO$ ).—This acid is common in living plants, and is the product of the eremacausis of all alcoholic fluids. It may be procured very readily and in a state approaching purity

by what is called the German method. A cask is filled with shavings previously soaked in vinegar; around the lower parts are holes to allow the access of air, and a stop cock to draw off any liquid from below; in the place of the common top a wooden tray is inserted, the bottom of which is pierced by numerous small punctures, through each of which is drawn a few strands of cotton yarn. Into this tray is poured alcohol diluted with eight parts water, mixed with about  $\frac{1}{1000}$ th part of yeast and warmed to  $80^{\circ}$  F. The dilute alcohol in streaming over the wood shavings is oxydized and partially converted into vinegar; by sending this product through a second or third time it becomes very strong; and thus vinegar can be obtained in thirty-six hours, superior to that formerly had by exposing wine and cider in half empty casks to air for months. In this process, the shavings become quite hot, from the action of the oxygen on the alcohol. The change here is as follows:



It is also found among the products of the destructive distillation of wood, and hence called pyroligneous acid; but to obtain pure acid it is necessary to distill dried acetate of soda mixed with sulphuric acid.

*Characters.*—Pure acetic acid is a colorless, limpid fluid, of a pungent refreshing odor, volatile; it boils at  $218^{\circ}$  F., and has the sp. gr. of 1.063. At  $50^{\circ}$  F. it crystallizes in large plates—this is called glacial acetic acid.

*Properties.*—It is a powerful acid, and its atom of water is basic and replaced by metallic and other oxides. Its true form being  $HO, C_4H_3O_3$ , or according to the hydrogen theory  $H + C_4H_3O_4$ , it is monobasic. The vapor is inflammable. It has a strong affinity for water, forming a definite compound with two atoms; it also mixes with alcohol and ether, and dissolves camphor, the essential oils and many vegetable principles—hence it is employed as a solvent in pharmacy. It is a valuable antiseptic.

*Uses.*—It is chiefly employed as an antiseptic body for the preservation of vegetables, and may be used for meats. In the laboratory it is useful as a solvent, and in medicine it is occasionally employed as a refrigerant in a diluted state. The strong acid applied to the skin is rubefacient. Pickles are often employed at the table, and seem to do little harm to those in sound health, but are injurious to the dyspeptic and feeble, impeding, in

some degree, the function of digestion by the antiseptic action of the vinegar; but, as they are usually combined with peppers and stimulants, this may be compensated. It enters the system, and becomes changed by the oxygen of the blood, in common with all the vegetable acids, into carbonic acid and water. Its salts, the acetates, are in the same way converted into carbonates.

*Salts.*—The acetates are readily formed by the action of the acid on metallic oxides or their carbonates, most are soluble, and all such are precipitated by the nitrates of silver or mercury of a white crystalline appearance. But the most characteristic sign of the acid is its odor, which may be produced by warming the acetate with sulphuric acid. Several acetates are used in medicine and the arts, the chief of which are the acetates of ammonia, alumina, iron, lead, zinc, copper, and mercury.

*Acetate of Ammonia* ( $\text{NH}_4\text{O}, \text{AcO}_3$ ) crystallizes in needles, which are very soluble, and have a saline taste. It is readily procured in solution by adding carbonate of ammonia to the dilute acid, and constitutes the *spirit of mindererus* of pharmacy. It is a well known sudorific and refrigerant in febrile disorders. The old preparation contained empyreumatic bodies, which gave it also antispasmodic properties.

*Acetate of Alumina and the Peracetate of Iron* ( $\text{Fe}_2\text{O}_3, 3(\text{AcO}_3)$ ) are extensively employed in dyeing as mordants; the latter is also used in medicine as a mild chalybeate.

*Acetates of Lead.*—There are four acetates of lead, the principal of which is the neutral acetate, or *sugar* of lead. This consists of  $\text{PbO}, \text{AcO}_3 + 3\text{HO}$ ; it is common, in bright, colorless rhombic prisms, which are soluble, and have a sweet astringent taste. The solution reddens litmus paper. It effloresces in the air, undergoing a partial change into the carbonate. By heat it is resolved into *acetone*, carbonic acid, and the *sesqui-basic acetate of lead*  $3\text{PbO} + 2(\text{AcO})$ .

Fresh basic acetate of lead is a valuable astringent, and arterial sedative; there is no remedy so valuable in hemorrhages. It is, however, poisonous in large doses, though much less so than is supposed; but the old salt, partially converted into carbonate, is highly deleterious. To avoid this effect, it is best to administer it in solution, with sufficient acetic acid to render the mixture clear. Doses of twenty grains have been employed every two or three hours in hæmoptysis and dysentery, without injury to the system, and with the best effects on the diseases. Its antidote is sulphate of soda, which forms the insoluble sulphate of lead with the base. Painter's colic (*colica pictonum*), which is sometimes said to have been produced by this salt, appears to be due to the use of the carbonate chiefly, if not exclusively. It affects painters and those who employ white lead, which is the carbonate. The



disease is attended with painful colic, tormina, tenesmus, and a partial paralysis of the hands; it sometimes ends in introsusception. Previous to the foregoing symptoms, the action of the lead may be recognized by a blue ring around the neck of the teeth. A lemonade containing sulphuric acid is recommended to avert these pernicious effects. The *tribasic acetate of lead* ( $3\text{PbO}, \text{AcO}_3$ ) is found in the *extractum saturni* of pharmacy; it has an alkaline reaction, and is very poisonous.

*Acetates of Copper.*—The principal is purified *verdigris*, ( $\text{CuO}, \text{AcO}$ ), which forms soluble, green crystals of a metallic taste. It is used as a paint, and is an irritant poison and emetic, similar to the sulphate of copper or blue vitriol. The coarse verdigris of wine countries, made by exposing old pieces of copper to the action of the husks of grapes, undergoing eremacausis, is a subacetate ( $2\text{CuO}, \text{AcO}_3 + 6\text{Aq}$ ). This yields the above neutral acetate by solution in acetic acid. Verdigris is a constituent of the *mel æruginis*, a topical application to ulcers, but which is seldom employed.

*Acetate of Zinc* crystallizes in very soluble, pearly, oblique, rhomboidal plates: it has the properties of the sulphate, and is used in dilute solution as an injection, and as an astringent wash.

*Acetate of Mercury* ( $\text{HgO}_2 + \text{AcO}_3$ ) is a brilliant, white, crystalline body, sparingly soluble in water; it was formerly used in medicine, being a constituent of the famous pills of Keyser, and one of the first mercurials employed in Europe.

COMPOUNDS DERIVED FROM THE ACETYLE SERIES.—The chief of these are acetone, chloro-acetic acid and chloral. *Acetone* or pyroacetic spirit ( $\text{C}_3\text{H}_3\text{O}$ ) is one of the products of the dry distillation of acetate of lead. It is a limpid, colorless fluid, highly volatile, of a peculiar odor, sp. gr. 0.792, and boils at  $132^\circ \text{F}$ . It dissolves in water, alcohol and ether, and is very inflammable. This body has been recommended in chronic diseases of the air-passages, and as an antispasmodic. Kane entertains the view that acetone contains a compound base, to which he gives the name of *mesityle*, and the formula  $\text{C}_6\text{H}_5$ ; he describes several compounds of it. *Chloroacetic acid* is a white crystalline substance, obtained as one of the products of the action of the sun's rays on a mixture of chlorine and pure acetic acid. It is deliquescent, with a faint odor, and caustic taste; the solution is acid, forming salts with many bases. Its composition is  $\text{C}_4\text{HO}_4\text{Cl}_3$  or  $\text{C}_4\text{Cl}_3\text{O}_3 + \text{HO}$ , or hydrated acetic acid, in which three equivalents of hydrogen have been substituted by chlorine. *Chloral* is somewhat analogous, the composition being  $\text{C}_4\text{Cl}_3\text{O}_2\text{H}$ ; this is an oily, colorless liquid, with an acrid vapor.

Related to the acetylene series is *cacodyle* or *kacodyle*, and its compounds. This compound radical has the formula  $\text{C}_4\text{H}_6\text{As}$ ,

which is the same as acetylene + arseniuretted hydrogen, or  $C_4H_3 + H_3As$ , and may be regarded as a product of the union of these bodies. It has been isolated by M. Bunsen, and is a colorless, limpid liquid, of a powerful odor of garlic, extremely irritant and poisonous. It is spontaneously inflammable when brought into contact with oxygen or chlorine; the oxides or chlorides of cacodylene resulting. It forms numerous compounds with the haloid bodies, of which none except the oxide is much known; this is *Cadet's fuming liquor*. All these bodies are so fearfully poisonous, that they can scarcely be conceived to be useful in the arts or medicine.

## PRODUCTS OF THE DISTILLATION OF WOOD.

When wood is distilled in iron vessels at a red heat, a large number of bodies pass over, including water, inflammable gases, acetic acid, wood spirit and tarry bodies, and there remains behind charcoal. The most interesting of these products is wood spirit or Pyroxylic spirit, which resembles alcohol in its chemical relations, and contains a compound radical called methyle; and some of the substances extracted from wood tar.

METHYLE is a hypothetical body with the chemical peculiarities of ethyle, having the composition  $C_2H_3$ ; its principal compounds are as follows:

### *The Methyle Series.*

Methyle, symbol Me	-	-	-	-	$C_2H_3$
Oxide of methyle, ( <i>wood ether</i> )	-	-	-	-	$MeO$
Hydrated oxide of methyle ( <i>wood alcohol</i> )	-	-	-	-	$MeO,HO$
Chloride of methyle	-	-	-	-	$MeCl$

*Oxide of methyle; methylic ether; wood ether*,  $MeO$ , is made from the hydrated oxide or wood spirit in the same way as ether is produced from alcohol. Sulphuric acid forms with wood spirit the *sulphomethylic acid*, which is the analogue of sulphovinic acid, being a hydrated bisulphate of oxide of methyle  $MeO, 2SO_3 + HO$ , and an aqueous solution is decomposed by heat into oxide of methyle and hydrated sulphuric acid.

The oxide is a permanent gas, sp. gr. 1.617, very soluble in water, and burning with a pale flame. The solution has an ethereal odor.

*Hydrated oxide of methyle—wood spirit; pyroxylic spirit;  $MeO,HO$* .—This passes over with the first products of the distillation of wood, there being about one per cent. of it in the pyroxylic acid. It is separated from the acid by submitting it to distillation, and receiving only the first portions; this is neutralized

by lime; the clear liquid is then separated from some oil, which floats on the surface, and the sediment at the bottom of the vessel, and redistilled. It is a volatile liquid nearly colorless, of a peculiar odor, sp. gr. 0.798, boiling at  $152^{\circ}$  F., of a burning taste and inflammable. It closely resembles alcohol as a solvent, and is also a diffusible stimulus, acting on the system nearly like it, but is more disagreeable in flavor. It dissolves resins, and may be burnt in lamps as a substitute for alcohol. It is also one of the most powerful antiseptics known.

*Chloride of methyle* is an inflammable gas; the *iodide* is an ethereal fluid. There are also quasi-salts of oxide of methyle, with sulphuric, nitric, oxalic, acetic, formic and other acids, none of which are, however, used.

**DERIVATIVES OF WOOD SPIRIT.**—In the eremacausis of wood spirit, by exposing its vapor to the action of platinum black, and in other ways, *formic acid* is obtained. This bears the same relation to it, that acetic acid does to wine alcohol, and like it, contains a new radical,  $C_2H$ , called formyle. This has never been isolated, but it resembles acetylene in its compounds, many of which have been detected.

*The Formyle Series.*

Formyle, symbol Fo	-	-	-	-	$C_2H$
Hydrated teroxide of formyle ( <i>formic acid</i> )	-	-	-	-	$FoO_3, HO$
Perchloride of formyle ( <i>chloroform</i> )	-	-	-	-	$FoCl_3$
Teriodide of formyle ( <i>iodoform</i> )	-	-	-	-	$FoI_3$
Terbromide of formyle ( <i>bromoform</i> )	-	-	-	-	$FoBr_3$

**Formic Acid—Hydrated Teroxide of Formyle;  $FoO_3, HO$ .**—The direct method of procuring this body has been given, but it may be obtained by distilling ants (hence its name), or by the action of dilute sulphuric acid on sugar mixed with peroxide of manganese. It is a caustic acid, of great activity, colorless, of a strong odor, resembling that of ants; it boils at  $212^{\circ}$  F., and crystallizes at  $32^{\circ}$  F. The *formiates* are an extensive class of salts resembling the acetates and soluble, but are not employed.

**Chloroform—Terchloride of Formyle;  $FoCl_3$ .**—This may be obtained by the direct action of chlorine on chloride of methyle ( $C_2H_3Cl$ ) in the sun's rays; chlorine takes the place of two atoms of hydrogen and  $C_2HCl_3$  is produced. On a large scale it is formed by the distillation of a solution of chloride of lime with alcohol or wood spirit; the product is to be purified by shaking with water, digesting on chloride of calcium, and finally distilling from concentrated sulphuric acid. It is a colorless, oily, volatile fluid, of an agreeable, ethereal odor, and sweet, hot taste; its sp. gr. is 1.48, and boiling point  $141.4$ . It is inflamed with difficulty, and burns with a greenish flame. It is converted by an alcoholic

solution of potash into formiate of potash, and chloride of potassium. Besides this terchloride of formyle there are, according to Liebig, a proto and deutochloride.

Chloroform has been for some time recommended as a substitute for ether, being more agreeable in flavor and more active; an alcoholic solution is used as a stimulant, antispasmodic and narcotic; the dose is from five to twenty drops in a diluted state. We owe to Dr. Simpson, of Edinburgh, the introduction of this body into medicine as a soporific agent. It is more rapid in its action than ether, thirty drops producing insensibility, when the vapor is inhaled from a sponge placed between the teeth; but it is more irritating, and sometimes produces considerable bronchitic irritation and some debility. (*See ether for further remarks on the subject*). Iodoform and many other ethereal bodies, have also anæsthetic properties.

Iodoform and bromoform have not been employed. Bouchardat also announces a sulphuret  $\text{FeS}_3$ .

OTHER COMPOUNDS DERIVED FROM METHYLE AND FORMYLE.—Chlorine acts on the compounds of methyle in the same way as on ethyle, producing the gradual substitution of the hydrogen, but these compounds are only curious in connection with the doctrine of types.

Sulphuretted Hydrogen and solution of potash act on sulphomethylate of potash, on sulphovinate of lime, producing compounds in which the oxygen is replaced by sulphur. The former is termed *methyle-mercaptan*,  $\text{C}_2\text{H}_4\text{S}_2$ ; the latter *mercaptan*,  $\text{C}_4\text{H}_6\text{S}_2$ , which severally represent wood spirit and alcohol, with sulphur in the place of the oxygen. These are colorless fluids, with an odor resembling that of onions.

*Formomethylal*, or *Methylal*, is obtained by distilling wood spirit, oxide of manganese, and dilute sulphuric acid, and saturating the product with potash. It is an ethereal, colorless liquid, of an agreeable aroma, soluble in water, very inflammable, sp. gr. 0.855, boiling point  $107.6^\circ \text{F}$ . Graham regards it as a compound of an hydrated oxide of formyle ( $\text{C}_2\text{H}_4\text{O} + \text{HO}$ ) with two atoms of oxide of methyle or  $\text{FeO} + \text{HO} + 2(\text{MeO})$ , but Regnault regards it as a new compound, similar to acetal, and gives it the name of methylal.

#### OTHER PRODUCTS OF THE DISTILLATION OF WOOD.

Gmelin discovered an empyreumatic liquid in the wood spirit of commerce, to which he has given the name of *lignone*; it is also called *Hylite*—the existence of another light ethereal body has also been announced in the same fluid by Weidmann and



Schweizer, and called *mesite*; these form numerous bodies by the action of potash, sulphuric acid and other reagents. The tar which passes over is remarkably rich in compounds, and when distilled alone or with water, is resolved into several oily bodies, and pitch is left behind. Bituminous coal and resinous wood also yield tar, which have different properties from the above. Hence there are *wood tar*, *pine tree tar*, and *coal tar*.

*Wood tar* contains eupione, creasote, paraffine, pittakal, picamar and other bodies.—*Paraffine* ( $\text{CH}$ ), *tar oil stearine*, is obtained from the densest oil of tar; it is a volatile fat, remarkable for its chemical indifference.—*Eupione* ( $\text{C}_5\text{H}_6$ ) is derived from the light oil of tar; it is the lightest fluid known, having a sp. gr. of 0.655; is colorless, limpid, and of an agreeable aromatic odor; it burns with a bright, luminous flame.—*Picamar* is a viscid, oily liquid, of an intensely bitter taste, derived from the heavy oil of tar.—*Pittakal* is a dark blue solid, like indigo, obtained from the heavy oil.

*Creasote* is the only one of these products which has yet been put to any useful purposes. It is extracted from the heavy oil of wood tar, by a very tedious process. When pure it is colorless, of an oily appearance, with a high refractive and dispersive power. It has a penetrating odor of smoke and a caustic taste, its sp. gr. is 1.037, and the boiling point  $397^\circ \text{F}$ . It inflames with difficulty, and burns with a smoky flame: its composition is unknown. When creasote is added to water, about 1.25 per cent. is dissolved, but if water be slowly added to a large quantity of creasote, about 10 per cent. is taken up. Alcohol, acetic acid, and ether unite with it in any proportions. Concentrated sulphuric acid with heat blackens and destroys it, but potash unites readily with it, and forms a pearly crystalline solid.

It is a remarkable solvent of vegetable bodies, dissolving indigo, madder, litmus, dragon's blood, cochineal and other bodies when warmed with them. But its most remarkable property is its intense affinity for albumen and probably other compounds of proteine, which it coagulates even when in the dilute state; hence it is the most powerful antiseptic, as it hinders the changes occurring in ferments. The action of smoke in preserving meats, is due to the presence of creasote.

The dilute solution, which contains but  $1\frac{1}{4}$  parts in a hundred of water, coagulates albumen, and therefore preserves meats, imparting to them the flavor acquired by smoking. This solution is also powerfully styptic and desiccative. If an ulcer be washed with the water, the albuminous fluids on its surface become coagulated and form a white pellicle; when applied to a bleeding artery it forms a coagulum. In consequence of this property, a solution is employed as a styptic and stimulating lotion, and it is

understood that the *aqua Binelli* is of this nature. It is used in the concentrated state as a remedy for the toothache, a little being placed by a probe in the hollow of the tooth, coagulates the albumen of the nerve and renders it insensible. An ointment containing f3ss, to an ounce of lard, is employed as an application to chronic skin diseases, and as a stimulant to chronic ulcers. In these cases it acts like the tar ointment (*unguentum picis*) which contains creasote. It is not now used internally, for in the dose of a few drops it creates considerable gastric irritation with vomiting, and has proved fatal in thirty-six hours, in the dose of two drachms. The best antidote is white of eggs, to be followed by the removal of the contents of the stomach. Tar water, most empyreumatic oils and crude pyroligneous acid contain this body. In the ancient process of embalming, tar was employed, and the antiseptic agent was therefore creasote.

**THE EREMACAUSIS OF WOOD AND THE AMYLUM BODIES.**—When the trunk, leaves or other parts of a tree are exposed to moisture and air, they become slowly disintegrated. The first action is of the nature of fermentation, for carburetted hydrogen and similar gases pass off, and little oxygen is absorbed—moreover, the decay may be entirely hindered by saturating the wood with the metallic salts, which have antiseptic properties, as corrosive sublimate, sulphate of copper, iron, zinc, &c.; but after the first action, eremacausis sets in, oxygen is absorbed, and water and carbonic acid formed. By these changes, a brown or blackish friable body is produced, called *humus*; this, by the action of alkalies, becomes *humic acid*, and enters into combination with bases. The apocrenic acid is, according to Mulder, a humate of ammonia. Humus is insoluble, tasteless, solid, and nearly unchangeable; whilst the humic acid and humates rapidly decay in the air, yielding water and carbonic acid. If there be much nitrogen in the vegetable matter, it is first changed into ammonia and then nitric acid.

If these changes be carried on under pressure, the vegetable matter becomes converted into coal, and the variety, whether it be lignite, bituminous coal, or anthracite, depends upon the age of the substance, the temperature to which it has been submitted, and other causes. Lignite has the appearance of condensed charcoal, but is brown, and contains hydrogen, as well as carbon. Bituminous coal also contains hydrogen, whilst anthracite is nearly, if not altogether, free from this element. By subjecting bituminous coal to a red heat, it gives off carburetted hydrogen and other products, besides a tarry matter.

*Coal tar* differs from wood tar in its components, and more nearly resembles pine or common tar. By distillation it yields coal naphtha, naphthaline, carbonic acid, and other bodies; the last of these is almost identical with creasote. Coal naphtha is a

complex body, the bulk of which is a volatile oily body, of peculiar odor, and resembling eupione. There are found in various parts of the earth, as in Italy, Persia, Ohio, Trinidad and Barbadoes, in the West Indies, substances resembling tar, pitch, and naphtha. These are called mineral pitch, or *asphaltum*, mineral tar, or *petroleum*, and rock oil, or *naphtha*. They resemble the products of coal tar closely, and are supposed to arise from the action of volcanic heat, or the heat of the earth, on beds of bituminous coal.

*To Preserve Timber.*—It has been stated that the first action in the disorganization of wood is of the nature of fermentation; now if we hinder this from occurring the timber will be preserved. Mr. Kyan originally proposed corrosive sublimate (*bichloride of mercury*) for this purpose, and the process has been hence termed Kyanizing. The fresh logs are introduced into a tank containing the corrosive sublimate in solution, and this permeates the fibres of the wood in every direction, forming an insoluble and indestructible compound with the albumen and other proteine compounds susceptible of decay. In the course of a few days the timber is rendered proof against dry rot or fungus, and becomes only partially combustible.

It has been found that sulphate of copper, acetate of lead, acetate or pyrolignite of iron, and other metallic salts, which are very much cheaper than corrosive sublimate, answer the same purpose. To M. Boucherie we are indebted for great improvements in the preservation of timber. In his process, the operation is conducted in the forest, in spring and summer. The summit of the tree is first lopped so as to present a stick of timber, it is then sustained in the erect position by means of ropes and a proper mechanical contrivance, and then severed from the root in the usual manner. A temporary basin is next constructed in the upper end of the trunk, and a solution of pyrolignite of iron (common red liquor of the vinegar distillers) poured into it. This liquid entering the pores of the wood, gradually penetrates from above downwards, displacing the sap, which runs out from the cut surface in enormous quantities. As one portion of solution is absorbed, another is added, until its presence can be detected in the fluid streaming out below; and at this stage the operation is complete. The salt of iron acts by forming indestructible compounds with the albumen, and the wood will be found much heavier, and scarcely inflammable after the process. This is the cheapest, most ready, and quickest method of attaining the end in view.

Wood may be permanently dyed in the grain by introducing metallic coloring matters. A fine black is given by first passing a solution of oak bark, or any other substance containing tannic

acid through the trunk, and then following it by a solution of pyrolignite of iron; the two mix, and form tannate of iron, which is the basis of black ink. If a weak solution of the prussiate of potash be followed by a weak solution of the salt of iron, prussian blue is produced, dyeing the wood permanently. A fine yellow is formed, by first passing chromate of potash, and then acetate of lead. To succeed in these operations, a white wood with open pores is necessary, the tulip tree answers in many cases; and, secondly, the solutions must be feeble, otherwise the insoluble products entirely fill up the upper pores, and hinder the further penetration of the reagent. This constitutes the basis of a highly interesting and valuable art, which has not yet attained any development.

### OTHER COMPOUND RADICALS, AND THEIR DERIVATIVES.

Besides the compound radicals derived from the amylum series, already entered on, there are several closely allied to them which are produced by the fermentation of peculiar bodies, or within the structure of plants; the chief of these are amyle, benzyle, salicyle and cinnamyle. Others, as cumyle, allyle, &c., are scarcely determined, and are not of sufficient interest to detain us.

#### THE AMYLE SERIES.

AMYLE is a hypothetical body, supposed to exist in the oil derived from the distillation of whisky, potatoe brandy and other alcoholic fluids. It is the product of a peculiar fermentation. Its compounds are numerous, as appears from the table.

Amyle, symbol Ayl	-	-	-	$C_{10}H_{11}$
Hydrated oxide of amyle (potatoe oil)				$AylO + HO$
Chloride of amyle	-	-	-	$Ayl.Cl$
Iodide of amyle	-	-	-	$Ayl.I$
Acetate of oxide of amyle			-	$AylO + C_4H_3O_3$
Sulph amylic acid	-	-	-	$AylO + 2SO_3 + HO$
&c. &c.				

*Hydrated Oxide of Amyle—Amylic Alcohol; Fusel Oil; Potatoe Oil; Oil of Grain Spirits;  $AylO + HO$ .*—This is the body which imparts the disagreeable and penetrating odor to whisky and potato brandy; it passes over in large quantities in the distillation of these bodies from the fermented wash. In the pure state, it is a thin fluid, of a suffocating odor and burning taste; it is slightly inflammable; sp. gr. 0.818, and boiling point  $262^\circ F$ .



It has the structure of alcohol, and like it, forms an acid with sulphuric acid, the *sulphamylic* resembling the sulphovinic, except that it is not resolved by heat into an ether. The vapor of potatoe oil is very irritating, and if inhaled, causes spasmodic pains in the chest, with coughing and sometimes vomiting. The vapor slowly oxydizes in the air, and is converted into valerianic acid, by eremacausis.

The *acetate of oxide of amyle* is an ethereal body like acetic ether, and is acted on in the same way by chlorine.

*Compounds derived from the Amyle Series.*—In the same way that acetic acid is obtained by the oxydation of alcohol, so valerianic acid is produced by the eremacausis of amilic alcohol, and this is the chief of the derivatives of the amyle bodies.

VALERIANIC ACID ( $C_{10}H_9O_3$ ) is a thin, colorless, oily fluid, of the odor of the officinal valerian; it is acid, of a sharp taste, and burns with a smoky flame. It forms a compound with one atom of water, and is slightly soluble in that menstruum. This acid also comes over when valerian root is distilled with water, mixed with the pure essential oil of valerian, of which it appears to be an oxide, as this becomes changed into the acid by exposure to air.

As it is a medicine of great value, the process for obtaining the artificial acid in large amounts is useful. This is accomplished by adding one part of oil of potatoe to ten parts of a mixture of equal parts of quicklime and fused potash, heating them from ten to twelve hours by a bath of oil or fusible metal (a mixture of eight parts by weight of bismuth, five of lead and three of tin), raised from  $320^{\circ}$  to  $400^{\circ}$  F. When cold, the white mass is removed by breaking the vessel, quickly immersed into cold water, a slight excess of sulphuric acid added, and the whole distilled. Water and the hydrated valerianic acid pass over, and are readily separated. The hydrated acid is resolved by distillation into water, which passes over first, and then anhydrous acid.

The artificial acid is said to have all the properties of valerian, as a nervous stimulant and antispasmodic, but it is not used alone. Combined with quinine and zinc, it has been highly recommended. The valerianates are mostly soluble, and are decomposed by the stronger acids.

The *valerianate of zinc* is formed by the action of the diluted acid, with the assistance of heat on carbonate of zinc; the solution is filtered and evaporated until it forms crystals on cooling. According to Dr. Neligan it is a tonic and antispasmodic, of the highest value in neuralgias, and cases attended with loss of tone in the system, as hysteria. According to Devay and Neligan, the preparation is superior to an extemporaneous mixture of carbonate of zinc and oil of valerian. The dose is from  $\frac{3}{4}$ ths of a grain to one grain two or three times a day. All acids, the alkaline car-

bonates, most metallic salts and astringent solutions, are incompatible.

*Valerianate of Quinine* is another body of the highest value as a nervous tonic and antiperiodic. It is formed by digesting quinine with a strong solution of the acid with the assistance of heat. The dose is from one to two or three grains twice or thrice daily. It has to be exhibited like the above, almost alone.

*Chlorine* acts on valerianic acid, in the presence of light, nearly in the same way as on acetic acid, forming chlorovalerisic acid and chlorovalerosic acid, in the former of which three atoms of hydrogen are substituted, and in the latter four by chlorine.

#### THE BENZYLE SERIES.

Benzoic acid and the oil of bitter almonds contain this hypothetical radical, the principal compounds of which are :

Benzyle, symbol Bz	-	-	$C_{11}H_5O_2$
Hyduret of benzyle	-	-	$Bz_2H$
Oxide of benzyle ( <i>benzoic acid</i> )			$Bz_2O$
Chloride of benzyle	-	-	$Bz_2Cl$
Amidide of benzyle ( <i>benzamide</i> )			$Bz_2Ad$
&c. &c.			

*Hyduret of Benzyle—Oil of Bitter Almonds,  $Bz_2H$ .*—This, which is the pure essential oil of bitter almonds, is obtained from the cake left after the expression of the fixed or sweet oil; for this purpose it is macerated in water and then distilled. There passes over the oil, mixed with hydrocyanic acid and water, and to obtain it pure, it is formed into a paste with slaked or hydrate of lime, chloride of iron and water, and redistilled; in this way the hydrocyanic acid is separated. It is now a thin, colorless liquid, of great refractive power, agreeable and powerful odor, sp. gr. 1.043, and boiling at  $356^\circ$ . It is very volatile, soluble in 30 parts of water, and mixes with alcohol and ether. Its vapor is inflammable, and the oil exposed to air absorbs oxygen, and becomes changed into crystals of benzoic acid.

The pure oil is said not to be poisonous, but the oil of commerce, which has a yellow color, contains a variable amount of hydrocyanic acid, from eight to fifteen per cent., and is almost as active as the strong acid itself—one drop having killed a cat. This oil is used in medicine in the same cases as prussic acid, but it ought not to be employed from its very changeable nature, some old specimens containing no acid at all. Dissolved in alcohol, as the essence of bitter almonds, it is extensively employed in the kitchen and by the perfumer. Poisoning by it has several times occurred, and is to be treated in the same way as by hydrocyanic acid.

The oil is produced from the bitter almond, by a peculiar fermentation. The seeds do not contain it, but a principle called *amygdaline*, which is changed by the action of water and warmth in the presence of a ferment, derived from the albumen of the seed, and called *emulsin* or *synaptase*. The amygdaline is a white crystalline solid, readily extracted from the almond, peach, and other bodies by alcohol; in the pure state it is permanent, and has the composition  $C_{40}H_{27}NO_{22}$ . Mixed with water in the pulp of the almond, and thrown into fermentation by the emulsin, it becomes resolved into two atoms of bitter almond oil, one of hydrocyanic acid, &c., according to the following table:

1 atom of amygdaline	-	-	-	$C_{40}H_{27}NO_{22}$
yields				
2 atoms of oil of bitter almond	-	-	-	$C_{28}H_{12}O_4$
1 atom of hydrocyanic acid	-	-	-	$C_2H_2N$
1 atom of sugar	-	-	-	$C_6H_5O_5$
2 atoms of formic acid	-	-	-	$C_4H_2O_6$
7 atoms of water	-	-	-	$H_7O_7$
				<hr/>
				$C_{40}H_{27}NO_{22}$

This case is given because it explains the production of hydrocyanic acid in cherry laurel water, from peach kernels, &c., and an illustration of the frequency of the action of fermentation in organic bodies. A very similar action takes place in mustard, for the production of the acrid oil; which does not exist in the seeds, but is the result of the fermentation by *synaptase*, on a principle called *myrosyne*.

There is an isomeric body formed in the purification of the oil of bitter almonds, and called *benzoin*, which is a solid, little soluble, and reconvertible by a red heat into the oil; it also changes into benzoic acid, in contact with an alcoholic solution of potash.

*Oxide of Benzyle—Benzoic Acid, BzO.*—This is the product of the oxydation of the hyduret of benzyle, but exists in the balsams, especially gum-benzoin, from which it is readily obtained by sublimation. It is better prepared by boiling the pounded gum with hydrate of lime and water, filtering and partially evaporating the solution, then adding sufficient hydrochloric acid to unite with the lime. The benzoic acid crystallizes out in beautiful white scales of a pearly lustre, as the mixture cools. It may be had pure by pressing between the folds of a cloth, drying, and then subliming.

It is without odor when cold, but has a pleasant smell when warm; melts below  $248^\circ$ , and boils at  $462^\circ F.$ ; one part dissolves in 200 of cold and 25 of hot water. It contains an atom of basic water, which is replaced by metallic oxides in the *benzouates*, which are not important compounds. The vapor of the acid excites coughing.

Benzoic acid is not much employed in medicine, but it is regarded as a stimulating expectorant, diaphoretic and diuretic; and the properties of benzoin, tolu and other balsams, are attributed to its presence.

*Hippuric Acid.*—When benzoic acid is taken internally, *hippuric acid* is found in the urine. This is a prominent ingredient in the urine of cows, and herbivorous animals. According to Liebig, this acid is a regular component of human urine. It is allied to benzoic acid, being converted into it by the action of hot sulphuric acid; by heat alone it is resolved into benzoic acid, benzoate of ammonia, a fragrant oil and coaly body. Its formula is  $C_{18}H_8NO_5 + HO$ . In the pure state it exists in long, slender, milk white and brittle, square prisms, almost insoluble, with a bitter taste and acid reaction. It may be obtained in any quantity by taking benzoic acid and allowing the urine to putrefy, when it will be found in the crystallized state in that fluid.

The benzoate of ammonia is recommended by Dr. Seymour as a diuretic in gout.

*Other Compounds of Benzyle* exist, such as the chloride, formed by the action of chlorine on oil of bitter almonds; the compound with amidogene, called *Benzamide* ( $C_{14}H_7NO_2$ ), which is similar to oxamide; and also compounds with sulphuric acid (*Sulphobenzoic acid*), with sulphur (*Sulphobenzide*); with nitrogen, chlorine, &c., which are not of any known value.

#### THE SALICYLE SERIES.

It has been long known that the young bark of several species of willow, of the aspen and poplars yields a white, crystalline and indifferent body, of a bitter taste, and resembling quinine. This has also febrifuge qualities, and is termed *Salicine*. It is connected with a compound radical or basyle, *salicyle*, which yields several interesting bodies.

*Salicine* is obtained by macerating the young bark in boiling water, concentrating the solution, digesting with powdered oxide of lead, then acting on the mixture by sulphuretted hydrogen to separate the lead, filtering, and evaporating the solution until the salicine crystallizes out on cooling. It is to be further purified by redissolving, filtering through animal charcoal and re-crystallizing. Salicine differs from quinine in containing no nitrogen, its formula being  $C_{21}H_{14}O_{11}$ . It does not form salts with acids, and is much less active than that alkaloid. Sulphuric acid colors it of a deep red by which it may be readily distinguished from quinine.

It is associated in the bark of the aspen and other trees, with a sweet, silky body called populine, nearly resembling it in appear-



ance, but of a sweet taste, and not known to have febrifuge properties.

The principal salicyle compounds are—

Salicyle, symbol Sl	-	-	$C_{14}H_5O_4$
Hydrosalicylic acid	-	-	Sl,H
Salicylic acid	-	-	Sl,O
Iodide of salicyle	-	-	Sl,I
&c. &c.			

It will be perceived that the formula for the hypothetical radical is the same as that for benzyle plus two atoms of oxygen, showing how close is the connection of organic bodies.

*Hydrosalicylic Acid*—*Hyduret of Salicyle*; *Oil of Spiræa or Meadow Sweet*; Sl,H.—This artificial oil, procured by distilling a mixture of water, salicine and sulphuric acid, is identical with the fragrant natural oil of the *Spiræa ulmaria*. It is a limpid volatile oil, boiling at  $385^\circ$ , with acid properties. It contains the same elements as crystallized benzoic acid.

Mixed with a strong solution of potash, its hydrogen is replaced by potassium, and there is formed the *Salicyluret of Potassium* (Sl,K). This forms large crystalline tables of a golden yellow color, alkaline reaction and greasy feel. In a moist state, the crystals undergo spontaneous decomposition, changing to a sooty body called *Melanic Acid* ( $C_{10}H_4O_5$ ) and acetate of potash. Other salicylurets are also formed by bringing bases in contact with the acid. The oil of *Gaultheria procumbens* is supposed to contain a substance very similar to the hydrosalicylic acid.

*Salicylic Acid*, Sl,O, very much resembles benzoic acid, being readily sublimed, slightly soluble, &c.; its salts are scarcely known.

The compounds of *chlorine*, *bromine* and *iodine* are made by the action of these agents on the hyduret; they are not used.

**PHLORIDZINE.**—This is an interesting crystalline body derived from the bark of the root of the apple, pear, plum and similar trees, and closely resembling salicine in appearance and virtues. Ten to twenty grains are capable of arresting an intermittent as completely as quinine. It is obtained by the action of strong boiling alcohol on the bark cut into small pieces. The solution is filtered, and by distillation the spirit is removed; the crystals may be further purified by re-solution, and filtering through animal charcoal.

It forms colorless, silky prisms, is neutral, bitter, scarcely soluble in cold water, but readily dissolves in hot water, or alcohol. Its formula, according to Mulder, is  $C_{42}H_{23}O_{18} + 3HO$ ; hence it appears to be an oxide of salicine.

If we boil phloridzine with a dilute acid (except the nitric and chromic), it is resolved into a crystalline body called *phloretine*

and glucose; a similar change occurs when the same operation is carried on with salicine.

*Phloridzeine* is a rich red substance, soluble in ammonia, and precipitated by acids. It is formed by the action of air and ammonia on moist phloridzine, and has the formula  $C_{42}H_{29}N_2O_{26}$ , indicating the absorption of ammonia and oxygen. When evaporated to dryness in vacuo, and mixed with solution of caustic potash, it forms a rich blue solid, of a copper-like exterior, resembling indigo, and soluble in water.

#### THE CINNAMYLE SERIES.

The essential oil of cinnamon has a chemical affinity to oil of bitter almonds; it is also found to contain a hypothetical radical, of which several compounds are known.

Cinnamyle, symbol Ci	-	-	-	-	$C_{18}H_7O_2$
Hyduret of cinnamyle ( <i>oil of cinnamon</i> )					$C_1H$
Oxide of cinnamyle ( <i>cinnamic acid</i> )	-				$C_1O$
Chloride of cinnamyle	-	-	-	-	$C_1Cl$
&c. &c.					

*Hyduret of Cinnamyle—Essential Oil of Cinnamon;  $C_1H$ .*—This is obtained by distilling cinnamon with salt water; the oil passes over, is of a characteristic odor, and heavier than water. It is well known as a stimulating, aromatic and astringent substance.

*Cinnamic Acid;  $C_1O$ .*—When fine oil of cinnamon is exposed in a tall vessel to air, oxygen is absorbed, and it changes into a white crystalline body, which is cinnamic acid. This is found in old Tolu and Peruvian balsams, associated with benzoic acid, with which it is analogous. Indeed, if it be distilled with a mixture of strong solution of bichromate of potash and sulphuric acid, it is converted into benzoic acid; and finally water and oil of bitter almonds pass over. The *cinnamates* are mostly soluble, and resemble the benzoates. *Chlorine* produces a number of compounds with cinnamyle, when passed through oil of cinnamon.

#### THE VEGETABLE ACIDS.

THE vegetable acids are very common in plants; they usually abound in fruits, but some, as the tannic, are mostly found in the bark and root; others, as the oxalic and acetic, in the juices. They exhibit an excess of oxygen over the amylum bodies, and seem to be produced by the oxydation of these substances in the plant; for some, as the oxalic and acetic acids, can be obtained

artificially by this process. They are often associated with essential oils, especially in the bark and fruits, and as these products are remarkable for a deficiency of oxygen, the two classes of acids and oils may result from one action impressed on the amylum bodies. The acids are of subordinate importance; they can be scarcely considered as food, and their salts are, with few exceptions, of little value. The chief of those not yet described, will be found in the following list :

*Table of Vegetable Acids.*

Tartaric acid	-	-	-	$C_8H_4O_{10} + 2HO$
Citric acid	-	-	-	$C_{12}H_5O_{11} + 3HO$
Aconitic	-	-	-	$C_4HO_3 + HO$
Malic	-	-	-	$C_8H_4O_8 + 2HO$
Tannic	-	-	-	$C_{18}H_5O_9 + 3HO$
Gallic	-	-	-	$C_7HO_3 + 2HO$

**TARTARIC ACID**.—*Acid of Grapes*;  $C_8H_4O_{10} + 2HO$ ;  $\overline{Tr}$ .—This acid exists usually united with potash in grapes, tamarinds, the pineapple, &c. That in commerce is obtained from argol, which is a precipitate thrown down during the fermentation of wines, and consists of supertartrate of potash. A solution of this body being purified by animal charcoal and recrystallized, constitutes *cream of tartar*, and this being treated first with lime, and then with sulphuric acid, yields the tartaric acid. In the pure state it forms colorless crystals having a figure derived from the oblique rhombic prism, of an intensely sour taste, and very soluble.

It is a powerful acid, with bibasic action, the two atoms of water being replaced by metallic oxides. It is used in dyeing, in the formation of effervescing powders, and as a refrigerant. In over doses it is irritant; in such cases, magnesia serves as an antidote. In the laboratory it is used as a test for potash, with which it forms the insoluble supertartrate.

**Compounds**.—The principal salts of tartaric acid are the *bitartrate of potash*, supertartrate, or cream of tartar, well known as a refrigerant and laxative; it contains  $KO, HO, \overline{Tr}$ —the *tartrate of antimony and potash*, or tartar emetic, already mentioned in the chapter on antimony—the *tartrate of potash and soda*, Rochelle salt or salt of Seignette ( $KO, NaO, \overline{Tr} + 10Aq$ ); this is a beautiful salt, crystallizing in large, clear prisms; it has a mild taste, and is a gentle purgative and refrigerant, of great value in infantile complaints. The *tartrate of iron* is a mild chalybeate.

**Derivatives**.—There is an acid, isomeric with the tartaric acid, found in the grapes of the Rhine, and called *racemic* or *paratar-taric* acid. It is bibasic, and very similar to tartaric acid, but differs in the property of producing a precipitate with a neutral

salt of lime. The racemates are nearly identical with the tartrates in other respects.

When crystallized tartaric acid is exposed to a temperature of about  $400^{\circ}$  F., it melts, loses water, and becomes changed into first *tartralic acid*, then *tartrelic*, and finally *anhydrous tartaric acid*. These have the same formula as tartaric acid, but the amount of basic water differs; by contact with water they are all restored to the tartaric acid. Another body, called the pyrotartaric acid, somewhat resembling acetic acid, is produced by the destructive distillation of tartaric acid; the formula of which is  $C_6H_3O_5 + HO$ .

**CITRIC ACID**—*Acid of Lemons*;  $C_{12}H_5O_{11} + 3HO$ ;  $\bar{C}$ .—This acid gives the sour taste to the lemon and lime, and is common in numerous fruits. It is obtained by adding chalk to the clear juice of lemons, by which the insoluble citrate of lime is formed, and this is next decomposed by dilute sulphuric acid. The citric acid is found in the liquid, and is next purified and crystallized.

It forms clear prismatic crystals, of an agreeable and intense acid taste, is very soluble, and the solution, like that of other organic acids, undergoes change when kept. The acid is tribasic, and therefore forms a large number of salts; it is also dimorphous.

It is decomposed by heat, becoming brown and partly changed into the *aconitic acid* ( $C_4HO_3 + HO$ ), which is found also in the common wolfsbane (*Aconitum napellus*), and in the *Equisetum fluviatile*; if the heat be increased, other bodies appear with empyreumatic oil. By the action of nitric acid and heat, it is converted into oxalic acid; caustic potash, at a high temperature, also resolves it into acetic and oxalic acids. Citric acid is used in effervescing powders, and is refrigerant, but being much more expensive than tartaric acid, is less used.

**Salts.**—The citrates are, for the most part, soluble; they are made by bringing the acid in contact with the base or its carbonate. The *citrate of potash* is a slight diaphoretic and refrigerant. *Citrate of magnesia*, in the dose of an ounce and a quarter, is an efficacious purgative, and being without unpleasant taste, is recommended as a substitute for Epsom salts; it may be administered in lemonade. *Citrate of iron* is a beautiful substance, of a bright brown metallic appearance, and is a mild chalybeate; combined with quinine as the *citrate of iron and quinine*, it becomes a very valuable tonic, applicable to cases of general and nervous debility. The *citrate of iron and ammonia* is used in photographic operations.

**MALIC ACID**—*The Acid of Apples*;  $C_8H_7O_8 + 2HO$ ;  $\bar{M}$ .—This abounds in apples, pears, the orange, &c., and is mostly combined with the citric acid. It is a sour, deliquescent, colorless solid, which dissolves freely in water, but spoils by keeping;



it is also soluble in alcohol. The acid is bibasic, and it forms neutral and acid malates, which are not, however, employed.

When heated in a retort, it melts, and there is formed a volatile acid, called the maleic ( $C_8H_2O_6 + 2HO$ ), and a crystalline substance, which remains in the vessel; the *fumaric acid*,  $C_4HO_3 + HO$ , which changes by solution in cold water back to malic acid.

**TANNIC ACID** — *Tannin*;  $C_{18}H_5O_9 + 3HO$ ;  $\overline{Ta}$ . — It is very abundant in the bark of many trees, especially the oaks; the gall-nut contains a large amount of it, which is readily separated by water.

The acid is soluble in water and alcohol, has an astringent taste, but reddens litmus, and forms a light-brown powder incapable of crystallization. It may be obtained pure by placing pounded gall-nuts in a displacement apparatus, and pouring over it common ether; the fluid which drains through, separates into two parts, the lower of which is a concentrated solution of the tannic acid in water, and the upper consists of ether with coloring matters, gallic acid and other bodies. The aqueous solution is evaporated in vacuo, and yields the pulverulent acid.

Tannic acid is a powerful astringent, and has been of late years used in solution as an injection in the place of decoction of oak bark and other substances. It has also been given internally as a tonic and astringent in doses of gr. i. to gr. ij.

It possesses the remarkable property of forming an indestructible compound with gelatine, called *tanno-gelatine*, which forms the basis of leather. Its astringent action is due to its chemical effect on the gelatine of the mucous membrane. With the persalts of iron it forms a black compound, the tannate of iron, which is the coloring material of common ink; it is hence used as a test for iron. The tannates are not an important class of bodies.

An astringent body, present in catechu, called *catechin*, is slightly different from tannic acid, being crystalline, and incapable of combining with gelatine, starch, or the alkaloids. It is said to be convertible by heat into tannic acid; alkalies also convert it into two new acids, the *japonic* and *rubinic*.

**GALLIC ACID**,  $C_7HO_3 + 2HO$ , is formed by the spontaneous oxydation of a solution of tannic acid, when exposed to the air or oxygen. It forms feathery, silky crystals, nearly colorless, requiring 100 parts of cold water for solution, and only three of boiling water. It does not act on gelatine, but precipitates the persalts of iron of a bluish black color.

Related to this acid are the *Ellagic*, *Pyrogallic* and *Metagallic*, none of which are, however, of any importance in medicine or the arts.

## OILS AND FATS.

**OILY BODIES** have a close affinity; they all present a certain well known appearance, are combustible, usually lighter than water, almost insoluble in water, and stain paper more or less permanently. Whether derived from animals or plants, their nature is closely analogous, but there are a few, as cholesterine, cerebrie, choleic acids, &c., peculiar to animals, whilst palmitine or the solid oil of certain palm trees, the ricinic acid from castor oil, myristic acid from the nutmeg, and many volatile oils, seem to belong exclusively to plants.

They seem to be produced both in plants and animals by the deoxydation of sugar and bodies of the amylum series. In the butyric acid fermentation and the formation of oil of potatoes, and valerianic acid, this is apparent. It has also been determined by Arequin that sugar disappears as wax is produced in the sugar cane. As oils are remarkable for an excess of hydrogen and deficiency of oxygen, they are supposed to be produced in plants by some catalytic action by which the amylum bodies are split into acids and oils.

These bodies are regarded by Dumas as compounds of carburetted hydrogen ( $C_2H_2$ ) and he finds that many of them conform to this hypothesis, being oxides of this body.

The oils are naturally divisible into three classes:

1. Volatile oils and fats.
2. Saponifiable oils and fats.
3. The non-saponifiable oils and fats.

**THE VOLATILE OILS AND FATS—*Essential Oils*.**—These substances are readily recognized by their odor, which is often powerful; they are sparingly soluble in water, to which they impart their flavor, and readily dissolve in alcohol, ether and the fixed oils; the stain they communicate to paper is transient from the volatility of the oils.

Chemically considered, they are neutral and non-saponifiable, but many are acid, and nearly all absorb oxygen from the air, becoming converted into resins which are acids. As medicines they are stimulants and antispasmodics of different powers. Most of these substances are liquid, but some, as camphor, are solid; such are termed stearoptenes; many deposite a stearoptene under peculiar circumstances, the nature of which is unknown. The number of animal volatile oils known is limited, the butyric acid and other oils of butter (the capric and caproic), musk, and the oil of castoreum and analogous bodies, being the chief.

The volatile oils abound chiefly in the leaves, bark, roots and fruit of plants, from which they are extracted, by distilling with an abundance of water or salt and water. The heat drives the oil over with water, and condensation is to be effected in a good refrigeratory. The water always dissolves a little of the oil, and acquires its odor and flavor, but the large amount is found separate, either floating on the water or at the bottom of the vessel, according to the specific gravity of the oil.

*Essential Oils without Oxygen.*—These have the formula  $C_4H_5$ , or some multiple of it, and usually form resinous bodies by oxydation. They are oil of turpentine, juniper, savine, elemi, lemons, orange rind, copaiba, cubebs. It will be observed that most of these are powerful diuretics.

A crystalline body is obtained from oil of turpentine by the action of hydrochloric acid called artificial camphor, but it has not the properties of camphor.

*Essential Oils with Oxygen.*—These have the formula  $C_{10}H_{10}O$ , or something resembling it. To this class belong nearly all the essential oils, as peppermint, mint, origanum, camphor, &c.

*Essential Oils with Sulphur.*—These possess extreme pungency; the oil of garlic, assafoetida, horseradish, hops and mustard are of this class.

**THE SAPONIFIABLE OILS AND FATS—Expressed Oils.**—These are the fixed oils and fats of the bodies of animals, and may also be obtained by expressing oily fruits and grains. They are decomposed by heat, are insoluble in water, few dissolve in alcohol, but all are more or less dissolved by ether and the essential oils. They are commonly lighter than water, without any remarkable taste or odor when pure, and very inflammable.

Chemically considered, they are compounds containing one or more oily acids, united with an organic base called oxide of lipyle; their consistency depending upon the oily acid present. When these bodies are heated with potash or soda, they become decomposed, the oily acid combining with the base to form a *soap*. When the base is lime or oxide of lead, they form insoluble bodies or plasters, and the hydrated oxide of lipyle or glycerine is separated. In these respects, the fixed oils differ altogether from the volatile oils.

In medicine the oils are emollient and in large doses laxative, but their chief importance is as food, and for purposes of illumination. It has been found that, during the process of digestion, a large amount of fat is absorbed into the system—the blood, chyle and lymph always contain fats. Amylaceous bodies are also partially converted into fatty bodies in the system, and then absorbed. The office of the fat in the functions of the body will be considered in the article on respiration.

It may, however, be observed in this place that the process of fattening, especially in the domestic animals, depends considerably on the amount of these bodies in their food; but there is no doubt that cattle fed on potatoes, and other substances containing little fat, do form it from starch in their bodies. Grundlach determined in the case of bees, that they possessed the power of converting sugar into wax, although, as in the case of other animals, they usually depend on the fatty matters of plants.

The chief fats of the animal are stearine, margarine and oleine, and these exist in plants, and are of precisely the same composition. The principal constituents of fats are as follows:

*Stearic Acid*;  $C_{68}H_{66}O_5$ .—This is the acid of the solid fat or stearine of mutton, beef fat, lard, linseed oil, &c., which is obtained by expression from lard and soft fats, and is a crystalline waxy substance in the pure state. Stearine has been used to make candles, which nearly resemble spermaceti.

The acid is obtained by first saponifying with lime, then acting on the soap by an acid, as the sulphuric, and dissolving the free stearic acid by hot alcohol, from which it is precipitated in milk white needles on cooling. The acid has the characters of a fat; it is insoluble in water, tasteless, combustible, melts at  $158^{\circ} F.$ , is decomposed by heat, but has an acid reaction.

The stearate of potash is the basis of soft soap, the stearate of soda of the hard soaps. The stearate of lead is an insoluble substance, resembling the plasters. With ammonia, it forms a soft soap, which is a constituent of some of the liniments. The stearate of lime is insoluble, and is present in the liniment made with linseed oil and solution of lime.

*Margaric Acid*;  $C_{68}H_{66}O_6$  (or  $C_{34}H_{34}O_3 + HO$ , *Redtenbacher*).—From the formula, it will be seen that this has one equivalent more of oxygen than stearic acid, which it closely resembles, differing chiefly in forming crystals of a less brilliant appearance, and which melt at a lower temperature.

It is the acid of margarine, the solid constituent of human fat, and olive oil, this being a margarate of oxide of lipyle. Margaric acid appears to be formed in the human body from the stearine of food. The acid forms compounds with the alkalies and bases, similar to those of stearic acid.

*Oleic Acid—Elaic Acid*;  $C_{44}H_{40}O_4 + HO$ .—This is the acid of oleine or elaine, the fluid neutral oil of plants and animals, which may be separated by expression. Olive oil, lard, human fat, and all the soft fats contain a large amount of it. It is, however, difficult to obtain the oleine perfectly pure, as it suspends the other oils; but by the repeated application of cold, margarine and stearine may be separated; bleaching, and filtering through animal charcoal, remove any adventitious color.

In the pure state, oleic acid is nearly colorless; it freezes at about



20° F. into crystalline needles, has an acrid taste and acid reaction, is lighter than water, and mixes with strong alcohol.

The oils, which have a large amount of this substance, as olive and almond oil, do not dry like linseed, rape and nut oils, which consist chiefly of margarine and stearine. The *drying oils* owe their property to the absorption of oxygen, by which they become changed into resinous bodies, and any preparation, as boiling alone, or with litharge, acetate of lead, sulphate of zinc, which tends to clarify them, increases this disposition.

The oleates resemble the margarates and stearates. The oleate of lead is the basis of the adhesive plaster, and other oleates exist in the ointments and liniments.

*Cerebric acid* and *oleophosphoric acid* will be considered in the section on nervous matter.

*The bases of the Fats.*—Three bases are recognized: the *oxide of cetyl* or *ethyl*, which exists in spermaceti; *cerain*, found in wax; and *oxide of lipyle*, which is the base of oleine, margarine, stearine, butyrine. Of these, the oxide of lipyle, known in the hydrated state as glycerine, is the only one of interest in medical chemistry.

*Glycerine* is set free when the common fats are saponified; it is a clear, uncrystallizable fluid, of a yellowish color, without odor, of a sweet taste, and very soluble in water and alcohol, but not in ether. It is said to be of use in cutaneous affections. According to Berzelius, it is partly formed during saponification, the true base being the oxide of lipyle (not isolated). The oxide has the formula  $C_3H_2+O$ , and glycerine is a compound of two atoms of this with three of water, or  $2(C_3H_2O)+3HO$ . It combines with sulphuric acid to form sulpho-glyceric acid, which resembles the sulphovinic acid.

**THE NON-SAPONIFIABLE FATS.**—The most important of this class are: *cholesterine*, a crystalline component of the brain and of biliary calculi, and pathic growths of the lungs and other organs; *serolin*, a fat existing in the blood; and probably wax, which abounds in all parts of plants.

*Derivatives of the Fats.*—Several bodies, as the suberic, succinic and sebacic acids, are derived from the oxydation of the fatty acids, and exist in organic bodies, but do not belong to medical chemistry. The *succinic acid* is also produced by the distillation of fossil resin or amber; and the *sebacic*, which closely resembles benzoic acid, by the destructive distillation of oleic acid.

*Bodies nearly associated with the Oils and Fats.*—To this class belong the resins, amber, caoutchouc, gutta percha, cantharidin, and several oily principles resembling it, and extracted from plants by the action of hot alcohol or ether. The gum resins are

compounds of oily and resinous bodies with gum. The balsams contain oils and resins. A solution of resinous bodies in alcohol, or oil of turpentine, constitutes the varnishes of commerce.

Caoutchouc, or Indian rubber, has properties intermediate between those of an oil and resin; it is softened but not dissolved by ether, and yields a volatile oil, called *caoutchine*, by distillation, which is its best solvent. This solution constitutes a flexible varnish when applied over surfaces, and effectually excludes moisture. *Gutta percha* somewhat resembles caoutchouc, and is obtained from the sap of a tree called percha, in Singapore and the adjacent country; but it is much less elastic when cold. It softens by a heat of  $180^{\circ}$ , and then may be moulded into any form, hardening as it cools.

## THE COLORING MATTERS.

THE colors of plants and animals are due to particular principles, which are usually indifferent, but readily decomposed, and have different colors under the action of oxygen and some other agents, which affect their intimate structure. Thus indigo, when deoxygenized, is white instead of blue, and we are able, by the action of nitric acid, to give it a yellow color; there is also a brown and red product. The coloring matter of the human body offers similar variations; it is bluish-red in the veins, crimson in the arteries, yellow and green in the biliary secretion, and in certain diseases of the urine (cyanuria), has been detected of a blue color.

Thus the same body often presents many tints under the influence of reagents; from this fact we should infer that they are compounds of a radical, but at present few of these are known. As a general thing, acids convert vegetable blues into red, whilst alkalies convert reds into blues and greens, and yellows into brown—hence some colors, as litmus and turmeric, are used in the laboratory as tests of these substances.

Coloring matters are extensively used in dyeing, as many stain wool and cotton permanently; but to fix others, the acetate of alumina, chloride of tin and other bodies called mordants, are employed. These possess the double property of uniting with the coloring principle and fibre.

The coloring matters have some analogy in composition with the fats, some as chlorophyll, the green substance of plants, being converted into it; their formulas also exhibit a great preponderance of carbon and hydrogen.

These bodies are divided into two classes, those which contain nitrogen, and those which are non-azotized. To the first belong indigo, chlorophyll, hæmatin; to the latter, madder, hematoxylin, the red coloring matter of logwood, quercitrine, the yellow sub-

stance of the oak, turmeric, and other bodies of less importance. The non-azotized coloring matters are classified according to their colors, and have not been made the subject of so much examination as the azotized bodies.

*The Azotized Coloring Matters.*—Under this head we shall offer a few remarks on indigo, chlorophyll and hæmatin.

**INDIGO.**—This is obtained from numerous leguminous plants, of which the genus *Indigofera* affords the chief supply. The green plants are macerated in water until they ferment; by this means a yellowish solution is obtained; this is next drained off into a fresh vat, and beaten with flat sticks so as to drive atmospheric air into the mixture, by which flakes of a blue matter are formed, which precipitate to the bottom of the vat. When this is collected and dried, it constitutes the indigo of commerce.

It forms a deep blue solid, the exterior of which has something like the lustre of copper; it is insoluble in water, alcohol, oils, dilute acids and alkalies, but combines with strong sulphuric acid, forming the *sulphindigotic acid*, which is soluble in water. Pure indigo can be sublimed, and forms brilliant crystals of a cupreous lustre. Common indigo contains other bodies besides the pure blue coloring matter, which are separated by various processes.

There is no doubt that indigo is a compound of a hypothetical radical, called *Anyle*, the formula and compounds of which are presented in the table.

Anyle, symbol An	-	-	-	-	$C_{16}H_5N$
The hydrated protoxide ( <i>white indigo</i> )	-	-	-	-	$AnO,HO$
The deutoxide ( <i>blue indigo</i> )	-	-	-	-	$AnO_2$
The quadroxide ( <i>isatine</i> )	-	-	-	-	$AnO_4$
The hydrated quadroxide ( <i>isatinic acid</i> )	-	-	-	-	$AnO_4,HO$

*White Indigo*—*Indigogen*,  $C_{16}H_6NO_2$ , or  $AnO,HO$ —is the substance which exists in the fermentation vat; it is also prepared by deoxydizing blue indigo artificially. For this purpose, the dyer mixes 5 parts of powdered indigo, 10 of protosulphate of iron, 15 parts of slaked lime, and 60 of water, and beats them together by a suitable machine. The iron becomes changed into a peroxide, taking its oxygen from the blue indigo, and thus it becomes white, or deoxydized indigo, which is soluble in water. The foregoing is called the indigo-vat, for if cloth or other textile substance be dipped in it and afterwards exposed to the air, the coloring matter, by absorbing oxygen, becomes again insoluble blue indigo.

White indigo can be obtained from the above solution by neutralizing it by hydrochloric acid, when it falls in white flakes, which consist of minute crystals. The precipitate coheres as it dries, acquiring a silky lustre; it is tasteless, inodorous, insoluble in water, but soluble in ether and alcohol. In the humid

state it is readily changed into blue indigo by absorbing oxygen from the air. It is readily combustible.

*The quadroxide of Anyle—Isatine.*—This body is procured by oxydizing indigo; it forms brilliant red crystals of a prismatic figure, which contain two atoms more oxygen than blue indigo. It is slightly soluble in water, and becomes changed by contact with alkalies into isatinic acid by acquiring an atom of water.

*Sulphindigotic acid.*—This consists of a direct union of sulphuric acid with blue indigo, the formula being  $\text{AnO}_2 + \text{SO}_3$ ; but it is not a salt, for it has the properties of an acid, and is analogous to the sulphovinic acid. It is of a deep blue color, very soluble, and forms the soluble indigo, or sulphate of indigo of dyers.

A large number of bodies are formed by the action of heat with dilute and strong nitric acid, alkalies, and the haloid bodies, on indigo. Of these, it will not be necessary to mention more than two, the anilic and picric acids. *Anilic acid* is produced by the action of dilute nitric acid; it forms yellowish acicular crystals of a feeble acid taste, almost insoluble; by heat it is sublimed unchanged. This is sometimes called indigotic acid, and consists of  $\text{C}_{14}\text{H}_4\text{NO}_9$ ; it is, therefore, highly oxydized anyle, minus one atom of hydrogen.

*Picric acid—carbazotic acid;  $\text{C}_{12}\text{H}_2\text{N}_3\text{O}_{13}$* —is made by the action of strong nitric acid with heat; in the impure state, it was called the *Bitter of Welter*. When pure, it forms bright yellow crystalline scales, of a very bitter taste, and slight solubility. With potash it forms a salt which crystallizes in brilliant yellow needles, and explodes when heated. Many substances yield picric acid by the action of nitric acid—as silk, salicine, wool, &c.

From the foregoing it will be seen that, by slight changes, indigo may become a white, blue, red, or yellow compound; and it is this susceptibility to undergo variations in color, that constitutes the principal characteristic of this class of bodies.

**CHLOROPHYLL—Chromule; Viridine.**—These names have been given to the green coloring matter of leaves, which, however, consists of wax and coloring matter; to the latter only should the name chlorophyll be given. The green color is soluble in alcohol, ether, muriatic and other acids, and is converted into a light yellow by deoxydizing agents, in the same way that blue indigo is converted into white by the same action. The yellow chlorophyll is converted by heat into a red color perfectly analogous to the red color of fruits and some autumnal leaves.

Berzelius found also that the green of leaves consists of a mixture of a yellow, blue and dark matter; the blue being very similar, if not identical with indigo. From the observations of Berzelius and Mulder, it appears that there is a white or yellow coloring matter



(*Xanthophyll*), pervading plants, and having properties resembling those of resins and oils, which by oxydation becomes of a green color (*Chlorophyll*), and which, by further oxydation, is changed into red (*Erythrophyll*). The history of the reactions is complete; for the yellow in the presence of oxygen, becomes green, and the red, by deoxydation, also reverts to chlorophyll.

Mulder has succeeded in analyzing the green coloring matter of the poplar, and finds  $C_{18}H_9NO_8$ , a formula which is very analogous to that of indigo. In many other respects these bodies are closely related: chlorine produces a white precipitate in the solution of both; nitric acid converts both into yellow substances, and both unite with sulphuric acid.

The difficulty which has been found in the study of this body, arises from the very minute amount which exists in the leaf, and the tendency of the green matter to pass into the yellow and other bodies. It seems, however, pretty certain that indigo and other coloring principles are derived from this substance.

**HÆMATIN**—*Hæmatosine*; *Cruorin*.—The coloring matter of the blood is a deep crimson fluid, existing in the blood corpuscles, and lying between the interior nucleus of globulin and the transparent covering. In arterial blood its color appears to be much brighter than in the veins, the corpuscles in the latter having a deep purplish color.

By some authors this difference is referred to a chemical cause, whilst Mulder and others regard it as of an optical character. According to the first view the hæmatin of venous blood contains less oxygen or more carbon, but this has never been proved; on the contrary, numerous analyses have established the fact, that its elementary composition is identical, whether it be obtained from arterial or venous blood. The views of Mulder on this subject, are exceedingly curious and interesting. He conceives that the difference is merely that of tint, the globules of arterial blood having, as was originally shown by Hewson, a biconcave figure, and therefore reflecting a large quantity of light, and appearing of a brighter color, whilst the corpuscles of venous blood are nearly spherical and not concave; they therefore reflect much less light, and have a darker appearance.

In confirmation of this view may be cited the experiments of Scherer, who found that the admixture of white powders, as chalk, magnesia, plaster of Paris, gave to venous blood the arterial tint. Now these bodies exert no chemical or physical effect on the globules; they merely act to dilute the dark color, and render it brighter—precisely in the same way that a light, bright blue color is attained, by mixing a white powder with indigo or Prussian blue.

The action of white substances may, therefore, produce the

arterial tint without any absorption of oxygen or carbonic acid. This change can also be effected by strong saline solutions, especially of common salt, sulphate of soda, or nitrate of potash. These act by changing the figure of the globule, converting the spheroidal corpuscle of venous blood into the biconcave figure, which is said to characterize the arterial globules. This effect is produced by the powerful attraction of the above salts for water, which they can derive even from the interior of the globules, and thus their figure is changed as they become emptied of their contents, the sides collapsing more and more until the biconcave shape is reached.

The passage outwards (*exosmosis*) of fluid from the blood-cells, is not a peculiar phenomenon, but takes place in all cases where a cause of attraction exists exteriorly to any animal or vegetable cavity. The reverse also occurs, or the interpenetration of fluid (*endosmosis*), when the coloring matter or other contained principle of the cell has the greater attraction for surrounding fluids. Hence, if venous blood be poured into a saline solution, having a specific gravity of 1070 or more, it becomes bright crimson, and the globules collapse; again, if it be poured into pure water, the globules swell, become nearly black, and finally burst, the water having penetrated the cellule and distended it too much. The sp. gr. of blood is 1057, and saline solutions of this density neither contract nor dilate the corpuscles.

These experiments appear to decide the question and confirm the views of Mulder. Further confirmation is found in the circumstance that the amount of water is rather greater in venous than arterial blood, and hence the corpuscles have the means offered of becoming distended and biconvex.

*Composition of Hæmatin.*—On this point likewise there is some dispute, but we present that view of the subject which has received the sanction of Berzelius, Mulder and the highest authorities, and is sustained by experiment. Mulder found that when obtained free from globulin it has the formula  $C_{44}H_{22}N_3O_6 + Fe$ . It is soluble in water and alcohol; chlorine converts it into a white solid, removing the whole of the iron.

The iron was formerly supposed to be the cause of the color, and to exist in the state of oxide, but it has all the reactions of metallic iron, and may be entirely removed without changing the tint or properties of the coloring matter. These facts may be proved by the action of dilute sulphuric acid on hæmatin. This agent causes the evolution of hydrogen, which proves that the iron is in a metallic state; otherwise the gas could not be thrown off; there results from this chemical action oxide of iron, which, with the acid, forms protosulphate of iron, the red coloring matter remaining entirely deprived of the metal, of its characteristic hue.

*Chemical Nature of Hæmatin.*—Hæmatin unquestionably be-

longs to the catalogue of true coloring matters. It is indifferent, presents various colors under different circumstances, and has a formula which closely resembles that of indigo and chlorophyll. An atom of indigo has the composition  $C_{16}H_5NO_4$ ; this, elevated by three, gives  $C_{48}H_{15}N_3O_{12}$ ; therefore four atoms of indigo have a constitution resembling that of the compound of hæmatin with iron.

In confirmation of this connection, we would also refer to the various bodies derived from the red coloring matter of the blood: such as the yellow coloring matter of bile (*Cholepyrrhin*, Berz—*biliphæin*, Simon); the yellow coloring matter of the serum of blood itself (*hæmaphæin*), and of urine; the green color of some forms of bile (*biliverdin*); the blue coloring matter found in diseased urine (*uroglauclin*, Heller), and that belonging to blood (*hæmacyanin*); and lastly, the red body found in urine and termed *urrrhodin* by Heller, *uro-erythrin* by Simon, and *purpurine* by G. Bird. Of the foregoing coloring substances none have been analyzed except hæmatin, but Berzelius has determined that biliverdin is identical with chlorophyll; and it is equally certain that indigo occasionally occurs in urine, as *cyanourine*, a blue morbid product, closely resembles the vegetable color.

In addition to the foregoing tints, it may be inferred that there is a white state of the coloring matter, in the same way as there is found a white indigo and a white chlorophyll. The chyle and lymph entering the circulation are white; milk, and the secretion of pus which leave it, are also white. These substances may be without any coloring principle, but this is scarcely to be supposed, for chyle, lymph and milk injected into a vein speedily become reddened. It is therefore more probable that they contain a white hæmatin, which, coming in contact with the nascent oxygen of the blood, acquires a red color, precisely as white indigo becomes blue in the presence of moisture and oxygen. The black pigment of the eye, of melanosis, of freckles, of the negro, and which is occasionally found in urine, seems to be another form of hæmatin, which has not, however, been chemically examined.

Polli, an Italian chemist of celebrity, has established an intimate connection between the yellow coloring matter of the bile and hæmatin. He regards the former as produced from hæmatin, which has become effete, the one being an oxide of the other. A similar view is taken by Simon.

We are disposed, in view of these relations, to advance the idea that the coloring matter of the blood is derived, like fat and azotized bodies, from the food, and not produced by the metamorphosis of proteine bodies in the blood. Vegetable bodies contain some form of chlorophyll, in all their parts; this, when white, enters the lacteals directly, and if colored, is deoxydized by digestion, which is an emi-

nently deoxydizing process. Passing to the blood, it becomes oxydized along with other components of this fluid, and develops the blue and red tint, the former of which is less oxydized than the latter, and hence is in excess in venous blood. In the changes of the corpuscles the red yields to a yellow tint, and the function of the coloring matter is at an end; it is now excreted in the urine and bile. In these fluids, trifling circumstances, but little understood, give it a green hue, and reconvert it into the chlorophyll of the plant, which, it will be remembered, is a compound of a yellow and blue pigment. This view is further sustained by the resemblance of the formulas for indigo, chlorophyll and hæmatin, and the detection of a blue pigment in both the latter which may be considered identical with indigo.

The action of nitric acid on a solution of biliphæin also serves to establish the connection between the coloring matters of the body; this agent imparts to the yellow solution, first a blue tint which changes to a green, then to violet and red, and ultimately becomes brown. These changes arise from the progressive oxydation of the coloring matter by the nitric acid. The circulating fluid of many insects has a green color obviously derived from the coloring matter of the leaves they feed upon.

## THE VEGETABLE ALKALOIDS AND ALLIED SUBSTANCES.

THE vegetable alkaloids are very remarkable products, from the great medicinal activity they possess, from their basic properties, and from the presence of nitrogen in most of them. They are peculiar to certain plants, some being found in one species only, and exist usually combined with an acid in the bark or root, but some are found in the leaves, and others in the seeds.

The process adopted to obtain them in a free state, may be explained in general terms; but the reagents are different in different cases. A solution is first made of the active parts of the plant; this is accomplished by hot water, alcohol or ether, according to the body; the solution is next filtered, and treated with ammonia, magnesia, lime, or some active base, capable of uniting with the vegetable acid; the alkaloid is by this means precipitated—it is now to be separated from the supernatant fluid, and washed free from adherent impurities; the next step is to dissolve it in hot alcohol, or some other solvent, and digest with animal charcoal to separate coloring and resinous matters—by repeating this operation two or three times, and setting the solution aside, it usually yields crystals of the alkaloid. This may now be dissolved in acetic, hydrochloric or other acids, and evaporated to dryness; and thus the ordinary salts of the alkaloids are formed; or they may be



made by using an acid as the solvent, instead of hot alcohol in the latter stage of the above process.

The pure alkaloids are nearly all insoluble in water; hence their soluble salts are preferred in medicine, especially the hydrochlorates and acetates. This class of bodies is very numerous, and additions are being often made; their chemical history is, however, very imperfect, and their study belongs more especially to *Materia Medica*.

The following catalogue contains the principal bodies of this class, with the formulas of such as have been analyzed, and their medicinal properties so far as known. Those employed in medicine are printed in small capitals.\*

**ACONITINE**—*Aconitia*.—It is obtained from the officinal monkshood (*Aconitum napellus*), is a granular or glassy, colorless solid, of intensely poisonous properties. In small doses of gr.  $\frac{1}{20}$  to gr.  $\frac{1}{12}$ , it is an arterial and nervous sedative, but is seldom employed internally. An ointment or solution in alcohol, containing two grains to an ounce, is employed as an external application to the seat of severe neuralgic pains.

**Antiarine**;  $C_{14}H_{10}O_5$ ?—This exists in the *Upas antiar* or Java poison; it forms small, pearly crystals, and is one of the most fearful poisons in nature, producing convulsions and death when introduced under the skin in minute quantities.

**Asparagine**;  $C_8H_8N_2O_6$ .—It exists in asparagus sprouts, the roots of the marshmallow and other plants. When pure, it forms brilliant, colorless crystals, of a faint taste, and freely soluble in water. It cannot be considered an alkaloid, and has little medicinal activity, but may be considered a principle of food. By the action of an acid or alkali with heat and water, it is resolved into ammonia and the aspartic acid.

**Atropine**—*Atropia*; ( $C_{34}H_{23}O_6$ , Liebig.)—A white crystalline acid and bitter alkaloid, derived from the belladonna (*Atropa belladonna*).

**Brucia**. See *Strychnine*.

**CAFFEINE**—*Theine*; *Guaranine*;  $C_8H_5N_2O_2$ .—This substance, which imparts nervine properties to tea and coffee, exists also in the Paraguay tea, (*Ilex Paraguayensis*), and the *Paullinia sorbilis* of Brazil. It forms delicate, silky crystals, of a bitter taste, soluble, and capable of sublimation without change. Its alkaloid reaction is not established. It is a nervous stimulant and tonic of considerable power, and in minute doses may be considered a species of food.

**Chelidonine**;  $C_{40}H_{20}N_3O_6$ .—The alkaloid of *chelidonium magus*; it is scarcely known, but is irritant like the herb from which it is derived.

\* For a fuller account of these bodies see *Gregory's Chemistry* and *Gardner's Medical Dictionary*.

*Chiniodine*, found in the mother liquor of quinine, is this alkaloid mixed with impurities, and not, as was generally supposed, a new body.

*Cinchonine*. See *Quinine*.

*Colchicine*—*Colchicia*.—This is, according to Hesse and Geiger, the active alkaloid of colchicum. It forms slender, acicular crystals, of a bitter, biting taste, soluble in water, and much less acrid than veratrine. It is not separated for use, but appears to be a powerful poison, and to possess the properties of the colchicum.

*CODEINE*—*Codeia*;  $C_{35}H_{20}NO_5$ .—This is one of the alkaloids of opium, and differs in its formula from morphia, only in containing one atom less of oxygen. Its properties have not been satisfactorily determined, some considering it a nervous sedative, others a stimulant.

*Conicine*—*Conia*; *Cicutine*;  $C_{12}H_{14}NO$ .—This is a volatile, oily body, of a strong odor, obtained by distilling the alcoholic extract of the hemlock, *Conium maculatum*. It forms salts, and has the other properties of an alkaloid. It appears to be a nervous sedative, inducing a paralytic state of the spinal nerves, and arresting convulsions.

*Curarine* is a yellow, amorphous body, with alkaline reaction, obtained from the poison called *curari*, employed by the South American Indians to tip their arrows.

*Daphnine*.—This is a body resembling asparagine, derived from several species of mezereon, and not their active principle.

*Daturine*—*Daturia*.—An active body derived from *Datura stramonium*; it is colorless, crystalline, and has the odor of tobacco, and is thought to be identical with hyoscyamine. It has the property of dilating the pupil.

*DELPHININE*—*Delphinia*;  $C_{27}H_{19}NO_2$ .—An acrid, crystalline, whitish, and fusible alkaloid, obtained from the stavesacre (*Delphinium staphisagria*). It is recommended by Mr. Turnbull to be used in the same way as aconitine in rheumatism and neuralgias. The ointment may be made by mixing 3ss with an ounce of lard. It is not employed internally, and produces purging, burning pain, and convulsions.

*ELATERINE*—*Elateria*;  $(C_6H_{12}O_5, \text{Hennell})$ .—This is neither an acid nor alkaloid, but deserves a place in this catalogue from its great activity, being a violent purgative in doses of gr.  $\frac{1}{10}$ th. It is obtained from elaterium, which is the inspissated juice of the *Momordica elaterium*, by making an alcoholic solution, evaporating to the consistence of oil, and throwing it into boiling water; by this means a white precipitate of elaterine is obtained. When pure, it is crystalline, has a silky appearance, is very bitter, insoluble in water, but soluble in alcohol. If employed as a dras-

tic, hydragogue purgative—a dose of the  $\frac{1}{16}$ th of a grain will be sufficient in the commencement. A fifth of a grain has been known to kill a rabbit.

**EMETINE**—*Emetina*;  $C_{35}H_{25}NO_9$ .—The active alkaloid principle of ipecacuanha. When pure, it is white, pulverulent, slightly bitter, fusible at  $122^\circ$  F., and very soluble in alcohol and acids. It produces vomiting in doses of  $\frac{1}{16}$ th of a grain, and two grains are sufficient to kill a dog. There seems to be no advantage in separating it from the root, and it is therefore seldom kept by druggists.

*Gentianine* is the bitter principle of gentian, and extracted by ether. When pure, it forms golden-yellow needles.

*Hyoscyamine*, *Hyoscyamia*, is the active alkaloid principle of henbane (*Hyoscyamus niger*), and closely resembles atropine. It is white, crystalline, and has the property of dilating the pupil in minute quantity.

*Meconine*;  $C_{10}H_5O_4$ .—This is a crystalline neutral body, found in some kinds of opium, and said to be without activity.

**MORPHINE**—*Morphia*,  $C_{25}H_{20}NO_6$ .—The narcotic alkaline principle of opium. It forms small, colorless, brilliant, prismatic crystals, and dissolves in alcohol and dilute acids. It melts by heat, inflames, and at a red heat is entirely dissipated, strikes a bluish color with solutions of the persalts of iron, and becomes of an orange red, with strong nitric acid. It also decomposes iodic acid, liberating the iodine which may be detected by solution of starch.

Its principal salts are the muriate, acetate, citrate and sulphate. The first is most used in medicine, the usual dose as an anodyne being from an eighth to a quarter of a grain. It is also applied endermically in violent neuralgias.

*Narceine*—*Narceina*;  $C_{28}H_{20}NO_{12}$ .—A neutral crystalline body, derived from opium, and said to be inert. It forms a blue compound with iodine, and is changed to a light blue color by the dilute mineral acids. In its composition, it is related to morphia and codeia.

**NARCOTINE**—*Narcotina*;  $C_{48}H_{24}NO_{15}$ .—This sub-alkaloid principle exists in the free state in opium, and may be removed by ether, or it may be obtained from the residue opium which has been submitted to the action of cold water, by acidulating with acetic acid, filtering and adding ammonia to precipitate the narcotine. It may be further purified, by boiling on the precipitate alcohol, and collecting the precipitate which falls as it cools. It is a white, inodorous body, crystallizing in fine prisms, soluble in ether, essential oils, and acids. It does not appear to have any narcotic properties, but resembles quinine, and is largely employed in the East Indies, as a remedy in intermittents.

*Nicotine*— $C_{10}H_8N$ —is the acrid oily alkaloid of cured tobacco leaves; it becomes thick and brown by exposure to the air. It appears to be a powerful narcotic poison, especially to insects.

*Picrotoxine*—*Picrotoxic Acid*.—A feeble acid derived from the *Cocculus Indicus* berries, and constituting their active principle. It is a white crystalline body, slightly soluble in water, and very soluble in alcohol and ether. It possesses the properties of the berries.

PIPERINE;  $C_{34}H_{19}NO_6$ .—It is a white or yellow crystalline body, tasteless, and having the characters more of a resin than alkaloid. It is procured from the peppers and from cubebs. It appears to be a valuable febrifuge, even preferable to quinine; the dose to cure an intermittent is, according to Mali, from 40 to 60 grains administered in alcoholic solution, in the same way as quinine.

QUININE—*Quinia*;  $C_{20}H_{12}NO_2$ .—The well known alkaloid of yellow bark. In the pure state it is white, rather amorphous, very bitter, and fusible at  $300^\circ F.$ , being converted into a yellow substance like resin. It is readily soluble in alcohol, ether, and acids. It unites with most acids forming soluble crystalline salts; of these the sulphate, citrate, and hydrochlorate are best known.

The common salt is the disulphate, and is almost insoluble in water, but by the addition of a little acid, it dissolves. The *arsenite of quinine* has recently been recommended in obstinate cases of intermittent; and the citrate of iron and quinine is an approved tonic and nervous stimulant.

The crystallized disulphate of quinine of commerce contains eight atoms of water of crystallization; it is fibrous, of a silky lustre, melts at  $210^\circ F.$ , then assumes a red color, and is entirely dissipated at a red heat without odor or residue. In small doses of one to two grains, this salt is a tonic, a nervous stimulant and febrifuge—when long repeated, producing headache, affecting the nerves of special sense, and causing a febrile condition. In the severe remittents of the south, it is often administered in doses of twenty to sixty grains, and appears to produce no injurious consequences, but to subdue the disease much sooner than if given in divided doses. It also acts as a prophylactic against intermittents, if occasionally taken.

*Cinchonine*, derived from the pale bark, differs from quinine, in containing one atom less oxygen, is more crystalline, and not so active as a medicine. *Aricina*, from cusco-cinchona, is another alkaloid; this contains one atom more oxygen than quinine; it is not used. Besides these, several other alkaloids are said to exist in the cinchonas.

*Solanine* is found in the stems of the dulcamara (*Solanum dulcamara*), and the young shoots of the potatoe. It is an acrid



alkaline body, crystallizing like the sulphate of quinine. A grain is said to have killed a dog.

**STRYCHNINE**—*Strychnia*;  $C_{44}H_{23}N_2O_8$ .—This active alkaloid is found in the nux vomica, and the barks of the species of strychnos, usually associated with *brucia*, which closely resembles it, and has the formula  $C_{44}H_{25}N_2O_7$ . It forms bright, small, octahedral crystals, without color, of an intensely bitter taste. It is scarcely soluble in water, but much more so in hot dilute alcohol. It forms well-defined salts with acids, of which the sulphate, muriate, acetate and nitrate are best known.

It is a violent poison, producing tetanic convulsions, stimulating the nervous system generally, and causing death by asphyxia; one grain proves fatal to a dog. Given as a stimulant in paralysis and other diseases, the dose is from gr.  $\frac{1}{40}$  to  $\frac{1}{12}$  gr. It is sometimes applied endermically as a violent irritant, a quarter to half a grain being used to the denuded surface. No antidote is known, but astringents are said to be useful.

*Brucia*, also derived from nux vomica, has the same medicinal properties, but not one-twentieth of the activity. It is readily distinguished from strychnine by its greater solubility in water and alcohol.

**Thebaine**—*Paramorphia*;  $C_{25}H_{14}NO_3$ .—An alkaloid body derived from opium, which somewhat resembles narcotine. Its medicinal properties are scarcely known; but it appears to be a nervous stimulant.

**Theobromine**;  $C_9H_5N_3O_2$ .—A substance resembling caffeine, obtained from cocoa seeds (*theobroma cacao*).

**VERATRINE**—*Veratria*;  $C_{34}H_{22}NO_5$ .—The alkaloid of several species of veratrum. When pure it is nearly white, pulverulent, of an acrid taste, fusible at  $240^\circ$  F., soluble in alcohol, but sparingly so in ether or water. Its salts have a gummy appearance. Locally applied in alcoholic solution or ointment it is a powerful irritant, producing heat and tingling, and is partially employed in neuralgias as a counter-irritant. Internally administered in doses of gr.  $\frac{1}{8}$  to gr.  $\frac{1}{4}$ , it produces irritation of the stomach and bowels with vomiting and costiveness, and anomalous nervous symptoms, but is rarely employed this way. A very minute portion produces violent sneezing when drawn into the nostrils.

## THE PROTEINE SERIES.

WE have referred to the formation of *Proteine*, the basis of animal matters, in the juices of the plant, by the combination of ammonia with some of the amylum bodies. This view is based on the fact that proteine bodies are converted into ammonia and a black substance, having the elements of water with carbon, by the action of hydrochloric acid, in the presence of air. This resembles the black substance produced by hydrochloric acid on sugar. The ammonia combines with the acid and the hydrated carbonaceous matter is precipitated. Thus one atom of proteine is resolved into four atoms of hydrated carbon, and six of ammonia, with the absorption of oxygen.

The reverse may take place as follows:

4 atoms of dextrine ( $C_{12} H_{10} O_{10}$ )		$C_{48}$	$H_{40}$	$O_{40}$	$N_6$
6 atoms of ammonia ( $N H_5$ )			$H_{18}$		
		<hr/>			
Yield		$C_{48}$	$H_{58}$	$O_{40}$	$N_6$
		<hr/>			
1 atom of proteine	-	$C_{48}$	$H_{36}$	$O_{14}$	$N_6$
22 atoms of water	-		$H_{22}$	$O_{22}$	
4 atoms of oxygen	-			$O_4$	
		<hr/>			
		$C_{48}$	$H_{58}$	$O_{40}$	$N_6$

As ammonia is always to be found in the juices of plants, and especially the young roots, where proteine bodies also abound; it is highly probable that the action here described does take place.

The proteine bodies of plants and animals contain sulphur, phosphorus and other bodies, from which the radical may be separated by long continued action at a temperature of about 120° F. with a moderately strong solution of caustic potash. By this means a solution of proteine in potash is obtained, the sulphur and phosphorus being separated and combining with the mineral. This is next filtered and then precipitated by the cautious addition of acetic acid; for if an excess be employed, the precipitate, which is proteine, will be redissolved. If the potash solution be too strong, the proteine will be decomposed.

In the moist state, proteine is a grayish-white gelatinous body, insoluble in water, alcohol, and ether, without taste or smell, and passing, when exposed to air, into the putrefactive fermentation.

It is soluble in alkaline solutions and dilute acids, but the strong acids, except the acetic and phosphoric, coagulate its solution. Upon drying it becomes a light yellowish, brittle solid, resembling gum Arabic in appearance, and in this state may be preserved for any length of time without change, if kept in dry air.

The reactions of a solution of proteine are very similar to those of albumen, caseine and fibrine. It is precipitated by many metallic salts, by most strong acids, by alcohol, creasote and tannin. Its presence is readily detected by the action of a little strong muriatic acid. This agent, assisted by heat, imparts to the proteine a pinkish color, which changes to purple and becomes ultimately black. It is also known by its insolubility in alcohol and ether, and by the precipitate formed in its acid solutions by the red and yellow prussiate of potash.

The formula for proteine derived from its compounds with chlorine (*chloro-proteic acid*), sulphuric acid (*sulpho-proteic acid*), tannic acid (*tannate of proteine*), and other bodies, appears to be  $C_{40}H_{31}N_5O_{12}$ , as interpreted by Mulder; Liebig has, however, given the formula  $C_{45}H_{36}N_6O_{11}$ , which is nearly similar, and to be preferred for several reasons. This composition is the same, whether it be obtained from vegetable bodies, albumen, fibrine, caseine, horn, hair, animal tissues, or any of the proteine compounds.

Some difference of opinion exists as to the entire absence of sulphur in proteine, but it is not of sufficient importance to throw doubt on the above formula, and the experiments advanced to sustain this view are, to say the least, liable to severe criticism.

Proteine is a true compound radical, and the most important body in organic chemistry, being the basis of those substances which are capable of sustaining life in animals. Without its compounds, animals could not exist, for they make up the various tissues of the body, as well as sustain life. Scherer, Jones, and others, have also proved that the proteinous compounds of vegetables are identical with the matters which exist in the bodies of animals, and by this remarkable discovery, have thrown a flood of light on the processes of digestion and nutrition. For, so far as these substances are concerned, they undergo no change in the stomach, being merely dissolved and passing directly into the blood to be employed in the reparation of the frame.

In consequence of the complex structure of this body it is extremely subject to the action of chemical agents. Exposed to the air in the moist state it absorbs oxygen and a variety of oxides of proteine are formed, but after a time decomposition occurs, carbonate of ammonia is evolved and putrefaction takes place. In these changes numerous interesting bodies are produced; the first oxides form the materials of the human body; further oxides constitute *diastase*, *ptyalin*, *pepsin*, the active fer-

ments of germination and digestion; and a still further state of oxidation yields *yeast* and allied ferments.

The action of nitric acid on proteine is interesting, and furnishes additional evidence of its derivation from ammonia and an amylaceous body. This agent converts it into *oxalic acid*, *ammonia* and a bright yellow, insoluble body, termed *Xanthoproteic acid*. It will be remembered that by the action of nitric acid on sugar and the amylum series oxalic acid is produced. The following table contains the most important compounds of proteine; the formulas attached are not, however, to be taken as expressing the absolute composition of the bodies, but only as approximations:

#### COMPOUNDS OF PROTEINE.

Proteine, Symbol $\overline{\text{Pr}}$	-	-	-	$\text{C}_{18}\text{H}_{35}\text{N}_6\text{O}_{14}$
Binoxide of proteine	-	-	-	$\overline{\text{Pr}}_2\text{O}_2$
Tritoxide of proteine	-	-	-	$\overline{\text{Pr}}_2\text{O}_3$
Sulphuret of proteine ( <i>caseine</i> )	-	-	-	$10\overline{\text{Pr}}_7\text{S}$
Globulin ( <i>another sulphuret</i> )	-	-	-	$15\overline{\text{Pr}}_7\text{S}$
Sulpho-phosphuret of proteine ( <i>fibrine</i> )	-	-	-	$10\overline{\text{Pr}}_7\text{P}_7\text{S}$
Albumen of the egg	-	-	-	$10\overline{\text{Pr}}_7\text{P}_7\text{S}$
Albumen of the blood	-	-	-	$10\overline{\text{Pr}}_7\text{P}_7\text{S}_2$
Muscular flesh	-	-	-	$\overline{\text{Pr}}_7\text{H}+\text{HO}$
Arterial membrane	-	-	-	$\overline{\text{Pr}}_7+2\text{HO}$
Mucus	-	-	-	$\overline{\text{Pr}}_7+3\text{HO}$
Chondrin	-	-	-	$\overline{\text{Pr}}_7\text{O}_2+4\text{HO}$
Horny tissue, hair	-	-	-	$\overline{\text{Pr}}_7\text{O}_3+\text{NH}_3$
Gelatinous tissue	-	-	-	$2\overline{\text{Pr}}_7\text{O}_7+3\text{NH}_3+\text{HO}$

**THE BINOXIDE AND TRITOXIDE OF PROTEINE.**—When albumen or fleshy fibre are boiled for a long time with water in a vessel exposed to the air they become resolved into two parts; one soluble, found in the soup, which is the *tritoxide*; the other insoluble, and containing more oxygen than proteine, the *binoxide*. These bodies exist ready formed in blood, and are in excess in the inflammatory product called the *buffy coat*. The production of oxides of proteine in blood will not be considered extraordinary, when it is remembered that this fluid consists of proteine bodies, in contact with oxygen. The excess of oxides in inflamed blood will also be recognized as a consequence of the increased respirations accompanying fevers, by which large amounts of oxygen are introduced into the frame. Whenever oxygen, in the course of disease, is retained in the blood instead of acting on the tissues, it will also produce the buffy coat.

The *binoxide* is the insoluble substance left after boiling fibrine for some hours; it does not dissolve in alcohol, but is soluble in dilute acids, potash and ammonia. In the dry state, it forms a



black, glossy, resinous body, which yields an amber-yellow powder. A solution in acids is precipitated by the yellow and red prussiate of potash.

This is the principal constituent of the buffy coat of the blood; it is also found in false membranes and in the globules of pus; but it also exists normally in arterial blood, for the fibrine of this fluid absorbs oxygen in the lungs and becomes changed in part into this and the tritoxide of proteine.

The *tritoxide* is very soluble in cold water, but not in ether or alcohol; the solution resembles that of jelly, and when it is evaporated away, it first forms a jelly-like body, but ultimately dries into a bright amber colored solid. The aqueous solution is precipitated by the dilute acids, tannic acid, chlorine and many metallic salts; with the latter the tritoxide forms double salts. It is not precipitated by the neutral salts of potash and soda, by dilute acetic acid, nor by the prussiate of potash.

It is found in the blood, being derived from the oxidation of fibrine in the lungs, and is one of the chief means of carrying oxygen throughout the system. It also exists in pus, being the substance formerly termed *pyin*, and is associated with the binoxide in many products of inflammation, as in false membranes. The nutritious matter of soups and beef tea consists chiefly of this body.

*Pus*, it has been said, consists of the binoxide and tritoxide of proteine, but these bodies are included in regularly organized cellules usually of the  $\frac{1}{3000}$  of an inch, but being sometimes as much as the  $\frac{1}{1500}$  and at others less than the  $\frac{1}{4000}$ th. The globules are usually tuberculated on their surfaces and not smooth, of a yellow color, in groups, opaque, tough and nucleated. They swim in a clear liquid called the *liquor puris*. This secretion is closely analogous with the serum of blood, and differs from it chemically only in the fact that its proteine compounds are oxydized. The cellules of pus differ with the morbid substance from which they are obtained, being sometimes smooth and at others elongated, and fusiform or cordate in the ichor of cancerous ulcers.

The diagnosis between pus and mucus, which are often confounded, is simple. If a little caustic alkali be mixed with mucus, it is dissolved, and forms a clear solution; but mixed with pus it converts it into a transparent gelatinous substance, which may be drawn out into threads.

*Other Oxides of Proteine.*—If the binoxide of proteine be treated by chlorine, it loses an atom of nitrogen and acquires three of oxygen, thus yielding a third oxide, which has not been named. By boiling yeast, a soluble substance is obtained, having

the formula of proteine, with eight atoms of oxygen. *Diastase* and *Pepsin*, as well as other ferments, may also be referred to this class of bodies; but the analytical evidence is still imperfect. For an account of diastase, pepsin and ptyalin, the student is referred to the article on digestion.

#### ALBUMEN, FIBRINE, AND CASEINE.

**ALBUMEN.**—The white of eggs, the serum of blood, and the coagulable material of the juices of plants furnish specimens of albumen. Like fibrine and caseine, it may exist in three states; in solution, in the hydrated form, and in the dry or anhydrous state. It is generally supposed that its soluble state is due to the action of a minute quantity of soda or other saline matter. In this state it is a glairy fluid, from which the albumen is readily precipitated by heat, creasote and other empyreumatic bodies, most acids, metallic salts, and by the red and yellow prussiates of potash. A very small amount of saline matter throws it down, because of the high equivalent of albumen. This is an interesting fact, as it is connected with the therapeutic action of metallic substances. Assuming the formula, as given, to be  $10Pr + S, P$ , its equivalent will be 5600, and this number will represent the quantity of albumen, which unites with one or two atoms of the metallic salt, or from 60 to 100 parts by weight.

In the dry state albumen is a bright yellow solid, resembling gum Arabic, neutral and without smell or taste. This slowly dissolves in cold water, forming a glairy liquid, which begins to coagulate at  $140^{\circ} F.$ , or if dilute at  $167^{\circ} F.$ , and becomes white and subsequently insoluble in water. Coagulated albumen does not, however, dissolve in water, but merely swells. The relation of albumen to reagents is similar to that of proteine. The solution is precipitated by every acid except the acetic, tartaric and tribasic phosphoric, which have also the property of hindering the solution from being coagulated by heat. A weak solution of potash, soda, or their carbonates, dissolve albumen.

*Tests.*—Albuminous solutions coagulate at  $167^{\circ} F.$  They are not precipitated by dilute sulphuric acid, or acetic acid, but ferrocyanide of potassium throws down a white precipitate from its solutions. Nitric acid, corrosive sublimate and electricity also coagulate it.

The detection of albumen in morbid fluids, especially the urine, has become a matter of importance in the diagnosis of many diseases. For this purpose, the clear urine is heated, and a drop of nitric acid added, when coagula are produced if albumen be present. If the amount be large, heat alone will produce coagula.

*Relations to the Animal.*—Albumen occupies the first position

in the proteine series. From this principle, derived from the blood, the various tissues are formed. It is the blastema or cell-food of the physiologist, and is competent alone to sustain every organ of the body. The egg contains no other proteine compound but albumen, yet in the metamorphoses which occur during incubation, this body, aided by oxygen, and the elements of the yellow oil of the yolk, yield flesh, the tissues, blood, blood globules, fibrine, vessels, claws, skin, feathers and various organs. Thus by the metamorphoses of albumen in the presence of water and oxygen, all the principles of the body are formed.

There are, however, varieties of albumen, that from the serum of human blood, containing two atoms of sulphur, whilst that from the white of egg contains but one, and is isomeric with soluble fibrine. The amount of saline matters, usually phosphates of soda, lime and magnesia, and sulphates, also differ in specimens derived from different sources.

Albumen is the chief constituent of the blood, of the chyle, brain and lymph. It is present in most excreted fluids, especially serous fluids, and when in excess, injures the health by depriving the body of a part of its nutrition. Albumen, in the urine, indicates inflammatory action of the kidneys, or when in excess, disorganization, as in Bright's disease. This important body is also thrown out in severe diarrhœas and in dysentery, and occurs in the fluid of leucorrhœa, in protracted cases, with emaciation.

It is the principal nutritious body of vegetable substances. In fruits, and the juicy parts of plants, it exists in the soluble state, but in the seeds is coagulated.

**FIBRINE.**—Fibrine exists in the soluble and coagulated state. In the former state it is found in the liquor sanguinis or plasma of the blood, in lymph, chyle and the juices of plants, but it spontaneously coagulates when these substances are exposed to the air. The coagulation of blood is an effect of this change. Fibrine has the tendency in coagulating to arrange itself into fibres or granules, especially if the blood be stirred or whipped with switches. This fact furnishes a test of its presence, and also enables us to estimate its amount in blood. For this purpose fresh drawn blood is whipped with twigs and the adherent fibrine removed, dried and weighed. After its separation, the fluid will not coagulate, nor does a stream of oxygen passed through it give the arterial color to venous blood.

Dry fibrine has a pale yellow color, is without taste or odor, and insoluble in water, alcohol or ether, but it swells in water. Its reactions are the same as those of proteine. In the blood it is found associated with about 2 per cent. of saline matter, and 2 to 4 per cent. of fat.

The proportion of fibrine in healthy blood is about 0.2 per cent., but is much increased in many inflammatory diseases. It answers a very important office in the economy, being the principal means of absorbing oxygen from the air in the lungs, and carrying it through the system. Moist fibrine has a great affinity for oxygen, and is therefore peculiarly liable to change, being converted into the bin-oxide and tritoxide of proteine very readily. In this case, the sulphur and phosphorus are most probably oxydized, and converted into sulphuric and phosphoric acids. Dr. G. O. Rees is of opinion that much of the animal heat arises from the oxydation of phosphorus in the system, which may take place in the above manner. This theory is not of much importance, however, for the amount of phosphorus in the blood is exceedingly minute.

*Its relations to the animal body.*—Fibrine may be regarded as a derivative of albumen, and is of far less importance. Indeed, as it is an isomeric body, a trivial cause is, no doubt, competent to convert albumen into this body. It exists in the plasma or coagulable lymph, and is probably connected with the organization of the tissues, but in this process appears to be converted into the hydrates and oxides of proteine, for muscular fibre, arterial membrane, mucus and chondrine do not contain fibrine, but the above bodies. Fibrine is not, therefore, a component of the tissues, but only of the animal and vegetable fluids.

*Tests.*—It is distinguished by its spontaneous coagulability, by its insolubility, and by having the reactions of proteine.

**CASEINE.**—This is the principal ingredient in the curd of milk; it also exists in leguminous plants, and has been obtained from tuberculous matter and other diseased products. It exists in the soluble form, united with a little soda, in milk, and in the coagulated state in cheese.

Its reactions are similar to those of proteine, but it is readily distinguished from albumen and fibrine, by the fact that it does not coagulate by heat. But if a solution be boiled in the open air, a pellicle forms on the surface, which is due to the action of oxygen. It is thrown down by all the dilute acids, but redissolves when they are in excess. Rennet, or the prepared stomach of the calf, as well as mucous membranes undergoing change, have the property of coagulating solutions of caseine. It is obviously a derivative from albumen, for milk contains no other proteine compound, whilst blood, from which this secretion is drawn, contains no caseine in solution.

*Milk.*—This is an emulsion of fatty matter (butter), soluble caseine and sugar of milk, in water. The fats are enclosed in the globules. The proportions of these bodies differ in the milk of animals. The following table gives the average composition in 1000 parts:



		Butter, &c.	Caseine.	Sugar.
Cow's milk	- -	40	63	28
Goat's milk	- -	40	80	40
Woman's milk	- -	29	32	36
Ass's milk	- -	12	19	62

From this it will appear that goats' milk is the richest, and asses' milk the poorest. The milk of women contains little more than half the caseine of that of the cow, and less butter; if, therefore, it be used to feed infants, it should be mixed with its weight of water, and slightly sweetened with sugar.

*Globulin.*—The substance which forms the nucleus of the blood corpuscles, is to be regarded a variety of caseine, and is probably derived from albumen, the phosphorus of which has been transferred to other bodies, or been oxydized by the oxygen of the blood.

*Crystallin* is another variety found in the crystalline lens, and some morbid products.

#### OTHER PROTEINE BODIES.

*Mucus.*—The viscid secretion of the mucous membrane consists of several parts; it contains globules and the rudiments of cells (*epithelium cells*), suspended in a thick fluid called mucin, which contains saline matters and has an alkaline reaction. Its reactions are those of proteine compounds, and it nearly resembles pus, but may be distinguished by the action of potash, which dissolves mucus, but converts pus into a ropy mass. According to the observations of Liebig, it is hydrated proteine ( $\overline{\text{Pr}} + 3\text{HO}$ ), hence its derivation from the albumen of blood is very apparent, as it differs from it only in the separation of sulphur and phosphorus, and the acquisition of water.

*CHONDRINE AND GLUTINE.*—Animal tissues, especially skin, serous and cellular membranes, aponeuroses, tendons and bones yield, when long boiled with water, a solution which coagulates on cooling and is called gelatine. Jelly, isinglass, glue and osteocolla are specimens of this substance.

The jelly derived from isinglass, skin, cellular tissue and bones is readily soluble in warm water. This variety of gelatine is called *Glutine*, and differs in composition and reaction from that obtained from cartilage, which is much less soluble, and is called *Chondrine*.

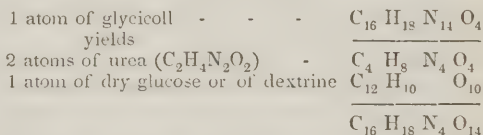
*Glutine* ( $2\text{Pr}, \text{O}_7 + 3\text{NH}_3 + \text{HO}$ ), according to the formula of Scherer, is a body considerably changed from proteine, being a compound of an oxide of proteine with ammonia and water. It is one of the final products of the metamorphoses of albumen; for ammonia is an effete product of the body. Hence, the gela-

tinous tissues are endowed with much less vitality than muscular fibre, and are to be regarded as occupying a position intermediate between it and the excretions.

Horn, hair, hoofs and bone yield a variety of glutine, the formula of which is,  $\overline{\text{PrO}_3} + \text{NH}_3$ , a direct compound of ammonia and tritoxide of proteine. These parts are nearly excrementitious and possessed of no vitality.

This principle is distinguished from *chondrine* in solution by not being precipitated by the acetate of lead, alum, sulphate of copper, acetic acid and sulphate of iron, all of which form insoluble compounds with *chondrine*.

On boiling glutine in an excess of solution of potash until ammonia ceases to be thrown off, it is converted into sugar of gelatine (*glycicoll*) and *leucin*. Leucin is a brilliant crystalline body, also derived from proteine by the action of potash; it is soluble in water and alcohol, consists of  $\text{C}_{12}\text{H}_{12}\text{NO}_4$ , and is, according to Mulder, an integral constituent of proteine. *Glycicoll* is soluble in water and alcohol; it has a sweet taste and forms colorless prismatic crystals, it is neutral, and unites both with bases and acids. It is a very remarkable fact that this body has a formula,  $\text{C}_{16}\text{H}_{18}\text{N}_4\text{O}_{14}$ , which is exactly resolvable into an atom of sugar and two of urea: or,



Urea is an effete product of proteinous bodies and the principal constituent of urine; it is also resolvable by fermentation in the presence of water into carbonate of ammonia. Hence glycicoll would appear to be formed in the disorganization of proteine into urea, and marks a stage in the processes of change in the body.

*Chondrine* differs from glutine in the action of reagents and in solubility. Its formula seems to agree with hydrated binoxide of proteine,  $\text{Pr}_2\text{O}_2 + 4\text{HO}$ . It is, therefore, not to be regarded as an effete product of the body, but as a principle remarkable for its permanence and indestructibility. It is extracted from the permanent cartilages.

*Gelatine* derived from either of these sources has several properties in common. Tannic acid precipitates them both from their solutions; this it effects even when there is but one part of gelatine in 5000 of water. Creasote and strong alcohol also precipitate it.

The action of tannic acid is interesting, for this body is the active ingredient of vegetable astringents and most tonics, and

there exists no doubt that these medicines act by effecting a direct union with the gelatine of the living tissues. The astringent effect is hence a result of the formation of an insoluble tannate of gelatine on the surface of the tissues, in consequence of which corrugation takes place, or the secretions of the part are arrested by a tough covering of tannate. Such remedies do not enter the blood, for the active principle is neutralized by the first contact with the gelatinous tissues: and if they did, death would soon ensue, for Mulder has calculated that the tannic acid of one ounce of cinchona bark injected into the blood would destroy its fluidity and produce instant death.

Leather is an impure tannate of gelatine, and gives us an idea of the toughness and indestructibility of this body. In its preparation a solution made from oak bark, sumach, hemlock and other astringent bodies, is employed, and made to combine with the gelatine of the hide.

Solution of gelatine, in common with the proteine bodies, if mixed with solution of sulphate of copper and then treated with a large excess of caustic potash, yields a magnificent purple color. But it does not answer to the test for proteine with hydrochloric acid; hence, although many chemists allow that proteine exists in gelatine, others deny it.

Gelatine is much used in the arts as an adhesive material, in the form of glue and size. It is also the principal constituent of jellies, and abounds in soups. Its value as food is not of so much importance as is generally supposed; but on this subject the student is referred to the article on food.

**MUSCULAR FLESH AND ARTERIAL MEMBRANE.**—These substances require no description. They are proteine compounds, for they answer to all the reagents, are soluble in alkalies, and precipitated from their solutions by the metallic salts, &c. Their relation to albumen is very simple, both of them containing hydrated proteine; hence, they differ from it in the absence of sulphur and phosphorus, and are readily derived from the plasma of the blood. These bodies, like all animal tissues, are associated with saline matters, and principally phosphates.

Liebig has observed, that the fluid which pervades the muscular portions of the body, has an acid reaction; and in this respect, differs from blood, chyle and lymph, which have an alkaline reaction. The acid action of the meat is due to the presence of the acid tribasic phosphates of soda and potash, while the alkaline property of the circulating fluids depends upon the alkaline phosphate ( $\text{Na}_3\text{PO}_6 + 2\text{NaO}$ ). This chemist is disposed to regard this difference of property as connected with the cause of nutrition and muscular action.

He has also detected  *kreatin*, a crystalline body discovered by

Chevreul, in beef tea, and also existing in the water extract of blood, in the liquids pervading the muscles of numerous animals. Kreatin is neutral, and dissolves in weak acids and alkaline liquids, but is changed into a base called *kreatinine*, by strong acids. Liebig observes, that kreatin contains the elements of glycoll and an atom of ammonia, and kreatinine of those of caffeine with one atom of starch. This may explain the property of tea and coffee, in appeasing the appetite and diminishing waste in the muscular tissues, which have been attributed to them.

It also throws light on the passage of proteine matters into urea, in the metamorphoses of the body. The kreatin being the substance primarily derived from the change of muscular fibre, and becoming, itself, converted into urea by further decomposition.



## PART IV.

### ANIMAL CHEMISTRY.

MANY of the substances already described, belong to animal chemistry, but most are, likewise, vegetable principles. In this place we propose, for the most part, to consider the chemical operations transpiring in the bodies of the higher animals, with their results, rather than the organic substances. To this consideration belong, digestion, absorption or capillary action, sanguification, respiration and secretion. These topics will be taken up in the above order, and such remarks included under each head as may elucidate therapeutics and pathology.

#### DIGESTION.

Digestion is the process to which food is subjected in the bodies of animals, to prepare it for the maintenance of life. In the carnivora it is much more simple than in herbivorous animals, who are provided with four paunches, or stomachs, to carry on digestion. This difference is due to the fact that animal aliment requires little change to sustain the body; but plants contain much that is innutritious, and which has to be separated from the nutritious portions. The digestion of animal food is also simpler, for it contains but two classes of bodies, proteinous and fatty substances; whilst herbs yield these, and an abundance of starchy bodies in addition. Hence, the digestion of vegetables and meats differ principally in two respects; that the nutritious matter is simpler and more condensed in meats than in plants. The process is also much shorter in the carnivora, and the amount ingested less than in the herbivora.

Preliminary to the study of the process of digestion, it is therefore necessary that the nature of food be considered; and on this topic we shall confine ourselves to the food used by man. After this, we shall consider the action of the saliva, gastric juice, bile and pancreatic secretion on the several aliments; and lastly, pre-

sent such facts as are known, concerning the formation of the chyle. This chapter, therefore, may be divided into four sections:

1. *The nature of food.*
2. *The office of the saliva in digestion.*
3. *The office of the gastric juice, bile and pancreatic secretion.*
4. *The chyle.*

### § 1.—THE NATURE OF FOOD.

Food is that which sustains one or more functions of the body. Every substance ingested will not sustain life, but may nevertheless, be valuable food. Those substances which are capable, alone, of maintaining existence, as bread, many seeds, and meats, are compound bodies, yielding on analysis proteine and amylaceous substances, or some form of proteine and fat. A combination of two of these bodies appears absolutely necessary; for cheese has failed to sustain dogs, and the same is true of fats, gelatine and sugar. Besides proteine, the amylum compounds and fats, other substances, as vinegar, gelatine, alcohol, and the caffeine of tea and coffee, may be considered food; for these sustain the body in part and are used as aliments.

The varieties of food have different values, and may be classified according to their relations to the tissues of the body, or the office they sustain. The former may be termed the chemical, and the latter the physiological classification.

### THE CHEMICAL CLASSIFICATION OF ALIMENTS.

According to this view, aliments are divided into eight classes—

1. *Azotized, Nitrogenized or Proteinous bodies.*—This includes those which contain nitrogen, and answer to the tests for proteine. Several substances, as glutine, yield nitrogen, but do not belong to this class. Albumen, as it exists in seeds and animal matters, is the chief principle of this family. The kinds of food in the order of their nutritiousness are—eggs, meats, milk, cheese, flour and the grains of the cerealea. A smaller amount of proteine bodies is found in roots and vegetables, none of which are entirely destitute of these principles.

This class has the highest value as food, for the proteine serves to repair the waste going on in the body, and recruit the blood; which is nearly a solution of proteine bodies.

2. *The Amylaceous Bodies.*—Starch, gum, pectin and sugar, are pure specimens of this class. These substances abound in fruits, potatoes, beets, carrots, other esculent roots, cabbages,

and vegetables generally. Corn, wheat, barley and grains, contain about fifty per cent. of starch, but also yield from 10 to 25 per cent. of proteine bodies, and are therefore placed in the former class. This kind of food is incapable of sustaining animal life even for a few days, and is but partially digested.

3. *Oleaginous Bodies*.—This includes the fats and oils with oxide of lipyle for a basis, and not the essential oils. Those derived from the vegetable kingdom, as olive, almond, linseed and bene oils, seem to be as serviceable as animal fats. This class cannot sustain life, but they are of the highest importance, especially in cold climates, where they are consumed in immense quantities.

4. *Acescent Food*.—Vinegar, and the vegetable acids which occur in fruits, belong to this class. These are all changed in the body, being converted into carbonic acid, hence it may be inferred that they serve some purpose, although they cannot sustain life.

5. *Alcoholic Food*.—The alcohol of wines, beer, cider, and spirituous liquors, are changed in the circulation into carbonic acid and water, and aid the process of calorification when used moderately. There is, however, a capital objection to them, that the amount consumed is often steadily increased until the health is impaired, and vicious habits formed.

6. *Gelatinous Food*.—Jellies, and those bodies which yield glutine, when boiled, constitute this class. They cannot sustain life, but they undoubtedly perform some function in the body. Liebig conceives that they serve to repair the tissues, especially the cellular tissue, which consists of glutine chiefly. They are far more useful to the invalid than amylaceous bodies.

7. *Caffeine*.—Tea and coffee undoubtedly satisfy the appetite, and render the necessity for animal food less than under ordinary circumstances. They do not, however, contain proteine, and cannot be employed in the reparation of parts, but probably act in diminishing the waste of this body. They serve to increase the urea of the urine, a principle which represents the waste of the proteine components of the body—hence the caffeine appears to be changed into this substance. Liebig also points out an interesting relation between theine, asparagine, and theobromine, and the bile, and considers that these bodies increase that secretion.

8. *Saline Bodies*.—Common salt, the phosphates of soda, potash, lime, and magnesia, and the sulphate of potash occur in the body. Most of them are introduced with meats and vegetable matters, but common salt appears to be deficient in ordinary aliments. Their office is highly important in the body, especially that of the phosphates of soda and lime, which are found in every part.

Bones contain from 40 to 60 per cent. of the phosphate of lime,

and the disease called *malacosteon* or *mollities ossium*, arises from a deficiency of this body. Hence, it has been recommended to introduce pounded bone earth into the food of such persons. Phosphate of soda would probably answer better, for the salt of lime is insoluble, and this substance would be converted into phosphate of lime within the system if it encountered any soluble compound of lime; and as this base occurs in water and most kinds of food, the change would most probably take place.

#### THE PHYSIOLOGICAL CLASSIFICATION OF ALIMENTS.

From the foregoing classification, it will be apparent, that all the principles existing in food, are not of equal service in sustaining the body. Those which contain proteine in such a state, that it can be readily separated, have the power of repairing the muscular and albuminous tissues, and recruiting the blood. This property belongs to no other kind of food.

It has already been observed, that proteine is exclusively the product of the vegetable kingdom, and cannot, therefore, be created within the bodies of animals. Hence, food which is capable of sustaining existence, must contain this principle. In the same way, other matters have specific offices in the frame, and they are classified according to their power to sustain one or other of its parts or functions. The classes are as follows:

1. *Proteinous Principles, which serve to recruit the Blood and Tissues.*—To this class belong meats, eggs, milk, and proteine compounds, wherever they exist.

2. *Gelatinous Food, which serves to repair the Gelatinous Tissues.*—Gelatine, in the free state derived from any of its forms, belongs to this class. MM. Bernard and Barreswil have shown, that but small quantities of gelatine, are assimilated by the blood, and that when administered by the stomach, or injected into the veins in quantity, it appears in the urine.

3. *Respiratory Food.*—Principles which are consumed in the body, for the production of the temperature necessary to sustain its functions. These bodies are ultimately converted into carbonic acid and water in the body, but sometimes pass through intermediate changes, and some of them are stored up in the body. To this class belong the fatty, amylaceous, acescent, and alcoholic bodies of the previous classification.

4. *Principles which arrest Waste in the Body.*—To this class are referred caffeine, asparagine, and theobromine, but nicotine, the active principle of tobacco, also possesses this property. Many vegetable alkaloids, taken in their natural combinations in plants, and in very minute amounts, probably act in this way, and owe



their remedial activity in large doses to the property of arresting the natural changes of the organs of the body.

Caffeine and asparagine, especially the former, are closely related in chemical composition with taurine, a compound of the bile, and seem to increase this secretion in health; but, on the other hand, serve to impede it in diseased states of the liver. There is no truth better established in practical medicine than that coffee and cocoa are injurious in diseases of the liver attended with a diminution of its function.

Morphine belongs to this list. Opium may become a necessary portion of food if taken for a long time, and it acts on the functions of the brain. In minute quantities it excites, and in large quantities is sedative.

Now, in the same way that caffeine is related to the bile, so morphine, codeia, quinine, strychnine and brucia are related to the principal constituent of the brain and nervous system—*cerebric acid*. This is a body, like the alkaloids, derived from proteine, and allied to the fats.

It is, therefore, inferred by Liebig, that these substances may act on the brain, like caffeine towards the liver. In minute amounts in health, they add to the changes of the organ (brain) and appear to increase its activity; but in large doses, or in disease, diminish or entirely arrest its action.

But as they are not identical in composition, each possesses a specific power, whilst all act on the nervous matter. Their effects are, therefore, not the same, but related in this respect, that they either excite or produce a sedative effect.

We are also inclined to attribute some portion of the action of opium to an influence on the capillary circulation, nor is this necessarily a secondary result, flowing from the sedative properties of morphine and some other alkaloids, for it is exerted when the agent is applied at a considerable distance, and where absorption occurs only to a limited extent. Its use in hemorrhages is of this kind, and its property of diminishing the secretions in diarrhœa and dysentery.

## § 2. THE OFFICE OF SALIVA IN DIGESTION.

THE morsel of food, comminuted by the teeth, is permeated by saliva in the mouth, and passes into the stomach in this state. The morsel will, in most cases, consist of proteinous, amylaceous and fatty matters, and the insalivation is a necessary and important stage of their digestion. The more so, if the food contains an excess of amylum bodies; hence the herbivora commonly chew the cud leisurely to insure this admixture. In the carnivora, it is a subordinate process; the flesh devoured by them

being moistened by the salivary secretion, but not so completely permeated as in the former case.

In man insalivation is an important operation, for his food contains a large amount of amylaceous bodies. Indeed, digestion cannot be properly conducted by him without due mastication, and much of the dyspepsia of our commercial cities arises from the hurried manner in which food is consumed. The absolute necessity of the saliva has been occasionally proved in cases where the secretion was diminished, or destroyed from disease of the glands. Professor Pattison saw a striking instance of this fact, in the case of a man who had cut his throat, and in whom the wound remained open for a long time. Nutritious food was administered by the severed orifice of the œsophagus, but the man rapidly wasted, and was on the eve of death from emaciation. It was observed, that whenever his meals were presented, an abundant discharge of saliva took place and ran out of his mouth, for he had lost the power of swallowing. The secretion had been formerly thrown away, but in consequence of his emaciated condition, attention was turned to it, and the Professor suggested that it should be collected, and introduced along with the food into his stomach. From this time the man improved, and finally recovered his health. From this striking case, it will appear that the saliva is essential to digestion in man ; hence we are interested in examining the nature and effects of this secretion.

*The Saliva.*—Saliva is a clear, glairy fluid containing corpuscles, having an alkaline reaction in health, and produced to the extent of about twelve ounces daily in man. Donné states that it is acid in gastric irritation, and inflammations generally. It is the product of the parotid and other salivary glands about the mouth, and is thrown out during the process of mastication. Its constitution in 1000 parts resembles the following :

Water	-	-	-	988.0
Solids	-	-	-	12.0
<hr/>				
Ptyalin	-	-	-	1.8 to 2.5
Fats, -	-	-	-	0.5
Albumen	-	-	-	1.7
Mucus	-	-	-	2.0 to 2.5
Saline matters	-	-	-	2.7

*Ptyalin* is the principal constituent. This has already been spoken of under the head of fermentation. From the experiments of Mialhe, Bouchardat and Leuchs, there exists no doubt that it is *diastase*. It possesses the fermenting powers of that body, and resembles it in its reactions. Mialhe directs it to be obtained, by adding alcohol to clear saliva as long as a precipi-

tate occurs. It is whitish gray, amorphous, soluble in water, but insoluble in strong alcohol, and has the animal odor of saliva.

Ptyalin, or animal diastase, converts solution of starch into sugar when it has an alkaline reaction, and otherwise acts like the vegetable principle. It is an oxydized proteine body, and a true ferment.

The alkaline reaction of saliva was formerly attributed to free soda; but Enderlin has shown that it depends upon the tribasic phosphate of soda with alkaline reaction ( $\text{Na}_3\text{PO}_6 + 2\text{NaO}$ ); the salt which is also present in the blood, lymph and chyle. This body is present to the extent of 28.0 per cent. of the ash, and gives to the ptyalin its characteristic action.

The principal portion of the saline matters consists of common salt (chloride of sodium), and phosphates of lime, magnesia and iron; but it also contains a small quantity of the *sulphocyanide of potassium*. This salt may be detected by a persalt of iron, added to a solution made by acting on dry saliva by alcohol. Dr. Wright states, that it is present to the extent of from 0.51 to 0.98 of the secretion, and is increased by the use of cyanides, and remarkably so by the internal administration of sulphur.

*Action of the Saliva.*—The presence of an active ferment, aided by the alkaline phosphate, constitutes this secretion an active agent in the digestion of amylum bodies. It possesses the power of converting starch into sugar, into oily matters like the butyric acid, and also acts as a lactic acid ferment. In mastication, every particle of food is enveloped in this mixture, and change soon takes place at the temperature of the body.

In addition to the foregoing, saliva possesses the property of absorbing a large amount of oxygen from the air included in the mouth. Dr. Wright found, that by warming it, as much as  $2\frac{1}{4}$  times its volume of oxygen was sometimes evolved; at others, the quantity was less, but never below one-half the volume. In this way, all the oxygen would not be separated; hence, we may conclude that saliva, during mastication, absorbs a large amount of oxygen, which does not directly enter into combination with the principles of this secretion, but is merely dissolved.

Hence, the saliva enveloping the particles of food, acts upon them as a ferment, producing from the amylum bodies the products indicated, all of which are among the results of digestion. This action begins in the mouth, and is continued in the stomach, so long as the saliva has an alkaline reaction; and we shall presently show that it occurs again in the small intestines, under the influence of the pancreatic juice, which is identical with the saliva. But the conveyance of free oxygen into the stomach, is an equally important office of the saliva, for upon this, the production of the gastric juice measurably depends.

### § 3. THE OFFICE OF THE GASTRIC JUICE, BILE AND PANCREATIC SECRETION.

*The Gastric Juice* is a yellowish, clear, acid fluid, thrown out from the villous coat of the stomach, by the stimulus of food. Without the presence of a stimulant, the villous membrane is pallid, and bathed with an alkaline mucus similar to that of ordinary mucous membranes. But a morsel of food excites it, the vessels become distended with blood and pour out a peculiar acid liquid — *the true gastric juice*.

If the stimulus be excessive, and the result of alkaline or active medicines, gastric juice is not formed, but a considerable discharge of mucus takes place, and vomiting occurs. For these facts we are indebted to MM. Blondot and Bernard.

The presence of food is not the only condition for the production of true gastric juice; but it has not yet been proved that the secretion thrown out, when indigestible and inert solids have been introduced into the stomach, is this body. On the contrary, the fluid so obtained is often alkaline; and in the case already cited from Prof. Pattison, digestion did not take place even when ordinary food was introduced into the stomach, because the saliva was withheld. These, and analogous facts, point out a connection between the saliva, moistening the bolus of food, and the production of the true gastric secretion.

Liebig has, on insufficient data, assumed, that the oxygen dissolved in saliva is the immediate cause of the secretion: that it oxidizes the mucus, or some other proteine body of the coats of the stomach, and this gives rise to the active ferment (*pepsin*) of the gastric fluid. Subsequent researches render this view extremely probable; for pepsin is found only in the true secretion, and is like ptyalin, an oxydized proteine body.

But the acid reaction of this fluid is no less characteristic, and this cannot be supposed to depend upon the action of the salivary oxygen. Indeed, Sandras and Bouchardat have shown that the secretion is connected with the action of the eighth pair of nerves; for on dividing them, the digestion of proteine bodies which depends on the acid, is stopped, but the digestion of amylaceous bodies goes forward. Matteucci has also shown that there exists a nervous (electrical) current between the stomach and liver, the action of which is, to give the villous coat of the former an acid reaction.

These facts lead us to the conclusion, that the oxygen of the saliva acting chemically on the proteine bodies of the villous coat of the stomach, generate pepsin; and that in virtue of this chemical action, a nervous (electrical) current is set up, which flows along



the pneumogastric nerve, and determines the decomposition of the phosphate of soda, the acid of which is destined to the stomach, and the alkali to the mucous tissue of the liver.

*Composition of the Gastric Juice.*—According to Gmelin, 1000 parts of the gastric juice of a horse contain :

Water,	-	-	-	984.00
Solids,	-	-	-	16.00
				<hr/>
Organic bodies,	-	-	-	10.52
Saline substances	-	-	-	5.01

This is a very unsatisfactory account of gastric juice, but more is known of the action of its constituents. The principal body in the organic portion is a ferment called *pepsin*; this has been insulated by Wassman, and subsequently by Vogel. It is soluble in water, but insoluble in alcohol and ether; it is precipitated by dilute acids, but redissolved in an excess. In the dry state it is a light brownish solid. It loses its activity by a heat of 104° F., and also by precipitation, by strong alcohol, strong acids, tannic acid, chlorine, acetate of lead, and metallic salts generally. Its amount in gastric juice is about  $\frac{2}{10}$ ths per cent.

Pepsin may be obtained from the villous coat of the hog recently killed, by repeated maceration with water for several days. It dissolves in the liquid, with mucus, albumen and other bodies; from these it is separated, by first adding acetate of lead to the solution, and subsequently passing a stream of sulphuretted hydrogen through the lead precipitate. The pepsin is found in the resulting solution, and may be obtained by evaporating it to the consistence of a syrup at a temperature not exceeding 95° F., and then adding absolute alcohol. A white precipitate of slightly impure pepsin is produced.

It is a true ferment, and very similar to diastase. A solution of it, containing one part in upwards of twenty thousand of water, and slightly acidulated by the hydrochloric or other acids, dissolves coagulated albumen in about six hours. But it has not this property, when neutral or alkaline; but on the reverse, the same action on starchy bodies as diastase or ptyalin.

Artificial digestion may also be accomplished by a mixture made by digesting any portion of mucous membrane, as a piece of bladder, in water exposed to air, and acidulating the solution. From this experiment we infer that pepsin is a mere oxide of proteine, and not a peculiar product.

The foregoing process of artificial digestion does not merely serve to show that fibrine, &c., can be dissolved out of the stomach, and that digestion is not, therefore, a vital process; but M. M. Bernard and Barreswil have shown, that the bodies so acted on being injected into the blood, are assimilated by that fluid

and serve to sustain life. They state that the assimilation is as perfect as that of chyle.

In healthy gastric juice, this ferment is associated with an acid, and has the property of dissolving coagulated albumen, fibrine, and casein, as well as some of their compounds. Flesh dissolves in from two to three hours under its influence. The nature of this *acid* has been a matter of dispute, but it is now decided by the experiments of Blondot,\* and Bernard and Barreswil,† that the acid reaction depends upon the presence of the acid phosphate of soda, or lime, and free lactic acid. Neither free hydrochloric nor acetic acids exist in the stomach.

The cause of the acid reaction is twofold. *Firstly*, the galvanic action, arising from the influence of the salival oxygen on the coats of the stomach. *Secondly*, the lactic acid is a product of the changes occurring on amylaceous bodies, by the ferment (ptyalin) of the saliva; this also serves to develop the acid phosphate.

*Action of the Gastric Juice.*—The gastric juice, whilst alkaline or neutral, aids the saliva in the digestion of amylaceous bodies, converting them into glucose, lactic acid, and oily bodies. When acid, it digests the proteine bodies, rendering them soluble. This action goes on in the stomach, along with the digestion of amylaceous bodies, for the morsel of food being first permeated with saliva, is subjected to its action, and only yields to the acid gastric juice, after the alkaline reaction of the saliva has been overcome.

Experiments made by Muller, Schwann, Tiedemann, Gmelin, Frémy, and Simon, show that fibrine is dissolved and converted into a body resembling albumen in the stomach, and by artificial digestion; that gelatine is dissolved and loses its power of gelatinizing; that sugar of milk becomes converted into lactic acid, and that starch is changed into glucose. Butyric acid has also been detected in the stomach of the horse, and exists in the fæces of man.

*The Bile and Pancreatic Juice.*—The partially digested matters which are driven out of the stomach, come in contact with bile and the pancreatic juice, as they enter the duodenum, both these fluids having an alkaline reaction, and neutralize the lactic and phosphoric acids of the gastric juice, and thus change the character of the digestion.

Of the bile, it is not necessary in this place to say more, than that it consists mainly of an oily acid (*choleic*) in combination with soda. The pancreatic juice appears to be identical with the saliva,

\* *Traité analytique de la Digestion*, Paris, 1843.

† *Journal de Pharmacie*, January 1845.

and has the same active principle, ptyalin, in connection with the alkaline phosphate of soda. It possesses the ferment action of saliva. Hence the instant the acids of the gastric juice are neutralized, the digestion of amylaceous and fatty bodies recommence, and it is in the lesser intestines that this chiefly takes place.

M. Blondot is of opinion, from his experiments, that bile exerts no influence on digestion, and so far as neutralizing the acid of the gastric juice is concerned, the pancreatic secretion may be sufficient. He states that its action is more apparent on the muscular portion of the intestines, than in the function of nutrition. This view is opposed to that of Professor Schwann and others.

I had an opportunity, some years since, of observing a very interesting case in a man, in whom the ductus communis choledochus had been obliterated eight months before death. He enjoyed some amount of health, was fat, but costive during the greater part of this period, and died of a dropsical affection. The liver was much reduced in volume, hard, and of a slate color. From this case it would appear, that digestion is not materially assisted by the action of the bile, but that it serves as a healthy stimulant to the bowels. The urine and perspiration in this individual, were of a dark yellow brown color, and served to separate, in a vicarious manner, the biliary matters from the blood.

#### § 4. THE CHYLE.

The purpose of digestion is to produce a milky fluid, called the chyle, which is absorbed by the lacteals of the intestines, and being conveyed through the mesenteric glands, reaches the receptaculum chyli and thoracic duct to recruit the venous blood.

Absorption from the matters introduced into the stomach, commences by the action of the veins of that organ. These take up water, alcohol, a small amount of glucose,\* and dextrine, albuminous matters, some quantity of oils and fats, and other bodies which enter the stomach in a state fit for assimilation. But the greater portion of the alimentary matters pass out of the stomach in a pulpy state, called the *chyme*.

The chyme contains proteine bodies, fatty substances more or

\* Majendie has made a series of important experiments on this subject, to be found in the *Comptes Rendus*, July 27th, 1846. He proves that glucose and dextrine are found in blood shortly after meals, in healthy dogs, horses, and pigeons. If a solution of dextrine be injected into the veins of a dog, it becomes transformed in the circulation, and does not pass out by the kidneys, but cane sugar is excreted. According to this chemist, the blood and animal fluids generally have the property of changing starch into dextrine and glucose.

less dissolved, dextrine, with undigested bodies, such as the husks of fruit, ligneous bodies, gelatine, &c., and has, when voided from the stomach, an acid reaction. Further digestion takes place in the course of the lesser intestines, and principally of fatty and amylaceous substances. Thus the chyme becomes gradually separated into a milky fluid called *chyle*, which is absorbed by the lacteals, and an insoluble matter, of a reddish color, which is excrementitious. The latter undergoes some changes, but little understood, in the cœcum.

In producing the chyle, it is thought that the biliary secretion acts an important part. It undoubtedly neutralizes acids, and determines the saponification of fats; and further it is understood, that a portion of the bile enters into the composition of chyle, and is re-absorbed. The coloring matter is effete and stains the fæces, but the choleic acid has not been detected in the undigested matters of the larger intestines. This being a fat, is probably thrown into the system again after undergoing assimilation.

*The Chyle.*—This milky, alkaline fluid, destined to restore the waste of the body, finds entrance from the lesser intestines into the lacteals of the mesentery, by capillary action. In some cases this fluid is pinkish, even in the first portions of the lacteals, but in the thoracic duct it is usually colored, and sometimes red. When there is much fat in the food, it is creamy and even yellowish. In the passage of this fluid through the mesenteric glands, it is supposed to acquire the greater portion of its fibrine from metamorphic changes impressed on its albumen and other proteine bodies, and it is said by Emmert, that the chyle of the lacteals, before it passes the glands, does not coagulate.

Chyle has never been analyzed from the lacteals, but that from the thoracic duct has been, both from the horse and dog. Here it is mixed with lymph, and is therefore impure, but there seems to be little difference between these fluids.

The thoracic fluid is opalescent, milky or red, according to circumstances; it abounds in globules, is alkaline, and spontaneously coagulable. The clot is soft, white or reddish, the serum is opalescent usually, and contains four kinds of globules—fat globules which are very numerous, especially after the ingestion of much fat; lymph globules which are round, colorless, and about three-fourths the size of blood globules; chyle globules, which are grayish or colorless, round, granular, and from one and a half to twice the size of blood globules; these are always found in the blood; and lastly, there often exist blood globules.

The following analyses, by M. Simon, of two specimens of thoracic fluid from a horse, will enable the student to perceive the affinity between this fluid and blood. The fat and saline



matters are in excess, and the fibrine, coloring matter, and albumen deficient as compared with blood.

	<i>Milky chyle.</i>	<i>Blood-red chyle.</i>
Water - - - - -	928.000	916.000
Solid constituents - - - - -	72.000	84.000
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Fibrine - - - - -	0.805	0.900
Albumen with lymph and chyle globules	46.430	60.530
Fats - - - - -	10.010	3.480
Hæmato-globulin - - - - -	traces	5.691
Extractive matters - - - - -	5.320	5.265
Saline matters, including phosphates, sulphates, } lactates and chlorides - - - - - }	8.400	7.550

It will appear from these analyses that the composition of chyle is subject to great variation. In the examinations of Tiedemann and Gmelin, the amount of fat fluctuated between traces and 16 in 1000 parts, and Dr. Rees gives 36 parts in the chyle of an ass.

Tiedemann and Gmelin have also made experiments with dogs to determine the influence of diet on this fluid and report as follows: Cheese reduced the coagulum; a starch diet yielded a pale yellowish white chyle; a mixed diet of bread, flesh and milk yielded a reddish firm coagulum with milky serum; milk alone also yielded a pink coagulum and white serum.

#### LYMPH.

Lymph resembles chyle in several particulars and answers the same purpose of recruiting the blood. But it is not derived from food introduced into the stomach, but from the excess of nutriment furnished to different parts of the system. It circulates in a separate apparatus of delicate vessels, furnished with valves, and called the lymphatics or absorbents, which, running near the veins are found in all parts of the bodies. They are often convoluted into glandular masses called the lymphatic glands, and finally terminate in the thoracic duct.

Lymph, for the purpose of examination, is usually obtained from the thoracic duct of an animal that has been fasting for several days. It differs in appearance, being clear, pink, yellowish, or opalescent, according to circumstances, is readily coagulable, and becomes of a deeper red by this change. It is alkaline, contains lymph corpuscles, which are colorless, and about  $\frac{3}{4}$ ths of the size of blood corpuscles, and nearly resembles the serum of blood. The following analysis by L'Heretier of lymph taken from a man who had fasted for thirty hours before death, presents the characters of this fluid.

Water	-	-	-	-	-	924.36
Solid constituents	-	-	-	-	-	75.64
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Fibrine	-	-	-	-	-	3.20
Albumen	-	-	-	-	-	60.02
Fat	-	-	-	-	-	5.10
Saline matters	-	-	-	-	-	8.25

But in other examinations the fat and albumen have been found in less quantities. This corresponds to a serum rich in fat and saline matters but poor in albumen. A result we should have expected, since the albumen of blood is its plastic component, which is employed in the reparation of parts.

The importance of the lymphatic system is usually overlooked. It constitutes a considerable portion of the tubular tissue of the body and contains a large amount of fluid. In cases of sickness, and starvation, this alkaline fluid exerts an active operation on the tissues, breaking them down and removing their contents, especially fatty matters. In health by its influence the supply of nutriment from the blood is regulated, and any excess removed and returned to the blood.

## THE BLOOD.

The blood is the nutritious fluid wherefrom all the parts of the body are to be supplied. The amount in a man is said to average some thirty pounds. It consists of the chyle and lymph after they have been prepared by the action of the lymphatic and mesenteric glands. This preparation is not understood, but one of its results seems to be the change of albumen into fibrine, for this important body is said not to exist in the lacteals before their passage into the glands.

But blood differs from the fluid of the thoracic duct, and this is attributed to three causes. 1st. That changes of metamorphosis occur in the blood itself; or that there is a sanguineous assimilation; for several of its constituents do not exist in chyle or lymph. 2d. Respiration by impregnating it with oxygen is a capital cause of change. 3d. The spleen, liver, kidneys and other organs by separating effete matters, or re-grouping some of its constituents, serve to assimilate its parts. The study of these changes, so far as they are known, involves the metamorphoses of the blood or its chemical history; the function of respiration and its consequences, calorification and nutrition; and lastly, secretion. Hence, for the consideration of the blood it will be necessary to divide the subject into three sections:

### 1. *The chemical history of the blood.*

2. *Respiration, calorification, and nutrition.*
3. *Secretion.*

### § 1.—THE CHEMICAL HISTORY OF THE BLOOD.

The blood is a somewhat thick, sizzly fluid, of a deep red color and alkaline reaction. The reaction is due to the presence of the phosphate of soda,  $\text{Na}_2\text{PO}_4 + 2\text{NaO}$ . Its specific gravity is from 1012 to 1058, arterial blood being slightly the heavier; but this amount of difference depends upon the fluctuating quantity of water present in this fluid. The temperature is from  $100^\circ$  to  $104^\circ$  F.: arterial blood being the warmer; under some circumstances, to the extent of two or more degrees. In the body, blood may be considered a kind of emulsion, its parts being of different gravities, and the globules insoluble and suspended in the fluid.

The globules, or corpuscles of the blood, are not of one size and color, but differ. There are sometimes found four kinds—true blood corpuscles, lymph, chyle and oil globules. The blood corpuscles are elliptical, flattened, colored, and about the  $\frac{1}{4000}$  of an inch in size; they are in great abundance, and are distinguished by their color. The lymph globules are colorless, round, of less size and delicately granular; they are found scattered through the fluid. The chyle globules have been described. Oil globules exist in the serum, and sometimes give it a milky color; they are spherical, and have a dark and well defined circular margin.

The blood globules differ, to a considerable extent, in animals, being least in the ruminantia,  $\frac{1}{5000}$  inch, and larger in the carnivora,  $\frac{1}{4000}$  inch.

In birds, fishes and reptiles, they are remarkably elliptical. The genesis of these bodies is scarcely understood; but, according to Barry, they are propagated by fissiparous generation. It would appear that they are also formed from changes imparted to the chyle and lymph globules; for it has been remarked, that milk globules injected into the blood, gradually disappear. Schultz, Henle and Simon, regard the lymphatic glands as concerned in the preparation of the globules; and that the lymph globules, by acquiring an envelope of coloring matter and a new cell wall, become red corpuscles. It would also appear, that these bodies pass through a series of changes, and originate in small white granular objects, which acquire color, and finally become of a brown tint and are lost to the circulation.

The cause of the color of the blood globules, and their composition, have been referred to, in the article on Hæmatin. The figure of the globules is influenced by water and saline solutions: the former distending them, and causing a rupture of their walls, whilst the latter contract them.

The *coagulation* of blood, which takes place a few minutes after

it has been drawn, results from the spontaneous coagulation of its fibrine. This constituent being dispersed through the blood, forms, by its solidification, a delicate network, which entangles the globules and fluid, reducing the whole to a gelatinous mass. But after a time it subsides, carrying with it the globules, and leaving the upper portions a clear fluid. The solid is called the crassamentum or clot of the blood, and the upper yellowish fluid, the serum or liquor sanguinis. The term *plasma* or *blastema*, is used to designate the natural fluid of the blood, in which its cells float, and is not to be confounded with the serum, for it contains fibrine and is susceptible of organization.

*The composition of the blood* in health is nearly uniform in the same animal, as respects its components, but their proportions are slightly variable. A hearty draught of water swells the amount of fluid in the blood, and on the other hand, prolonged abstinence from water diminishes its proportion. The sensation of thirst may be referred to the want of fluid in the blood; for, as it always contains saline matters, these exert an attraction for water; and if not satisfied by that existing in the blood, withdraw it from the tissues, and thus produce an effect which reaches the nervous system and awakens thirst.

In consequence of this difference in the proportions of its solid and fluid contents, chemical physiologists have sought for a normal or standard composition, which shall represent the blood in health, irrespective of trivial disturbing causes. The *normal* of Simon is as follows, in 1000 parts:

Water	-	-	-	-	-	798.556
Solid constituents	-	-	-	-	-	201.344
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Fibrine	-	-	-	-	-	2.208
Fat	-	-	-	-	-	2.713
Albumen	-	-	-	-	-	77.910
Globulin	-	-	-	-	-	100.890
Hæmatin and Hæmaphein	-	-	-	-	-	5.227
Extractive matters and salts	-	-	-	-	-	9.950

Or, in general terms, healthy blood may be represented as containing 20 per cent. of solids: of which there are 0.2 of fibrine, a similar amount of fat, and more globules than albumen.

Analysis also puts us in possession of the principal differences between arterial, venous and portal blood. *Venous* blood differs most remarkably from arterial blood, in containing more fatty and coloring matter, and a greater amount of extractive matter, which is azotized, but not yet thoroughly analyzed. *Portal* blood differs considerably from both arterial and venous blood; and probably from the fact that the branches of the portal veins act as absorbents from the stomach and intestines. It contains more than twice the amount



of fat of arterial blood, is much richer in hæmatin and hæmaphein, sometimes it contains more albumen, and appears, as a general rule, to contain less fibrine. It does not coagulate as readily as other blood, and is much blacker.

All the constituents of the blood except the fats, saline matters and water, are proteine bodies, so that it may be regarded a solution of them. Liebig has, from the analysis of dried blood, reached this conclusion, for he finds that the formula  $C_{48}H_{39}N_6O_{15}$  expresses dried blood and also a piece of flesh with its several parts of nerves, tissues, &c.

*Peculiar Components of Blood.*—There exist in the blood several peculiar bodies which do not appear to be derived from the chyle, and are hence supposed to originate in this fluid. To this catalogue, belong the globulin, which forms the nucleus of the blood globules, hæmatin and several peculiar fats, as cholesterine, serolin and a phosphorized fat. Its albumen also differs from that of eggs and plants, and is remarkable for the amount of phosphorus it contains.

Globulin contains no phosphorus, and is allied to caseine; hence, if it be derived from albumen the phosphorus must become attached to another constituent of the fluid; thus may arise the phosphorized fat. Fibrine also contains less phosphorus than the albumen of blood, hence another phosphorized product may result from this metamorphosis.

The hæmatin of blood may exist in the colorless state in the chyle and lymph globules, and acquire a red color by the action of oxygen in the lungs; or as in plants, this coloring matter may be the product of a change impressed on a proteine body.

There seems to be no doubt in the minds of physiological chemists that the blood globules, like every other organized tissue of the body, pass through changes of development, and finally become extinct. It has already been remarked that their first production is traced to the lymphatic glands, but the blood is the scene of their further changes. Here they acquire color, increase in size and finally become effete, adding to the amount of extractive matters and yielding the yellow coloring matter (*hæmaphein*,) of serum, bile and urine. But so long as the extractive matters are little understood, no clear history of the metamorphoses of the blood can be given.

The changes effected by oxygen, in respiration, on the fibrine and other constituents of the blood, belong to the following section. To the topic of nutrition belongs the introduction of substances from without, as urea, saline matters, &c., by which the composition of the blood is being continually changed, but only in a trifling degree during health. That changes are often impressed upon these substances by the blood is also highly probable, for if

we inject milk, glucose or other bodies into the veins they become gradually assimilated; whereas other substances, as cane sugar and gelatin, are said not to be affected. Majendie has also found that fresh blood possesses a catalytic action on numerous bodies, and that it is capable of converting a solution of starch into glucose, and finally causing the complete disappearance of the sugar.

**THE BLOOD IN DISEASE.**—The appearance, coagulability and composition of the blood is much altered in disease. Whether these differences result from the affections, or are consequences of them, is not understood; but it is probable that some are effects and others causes of disease.

There are, besides alterations in the proportions of its ordinary constituents, several bodies, as urea, glucose, bile, which may exist in it as impurities.

A classification of diseases has been proposed based on numerous analyses of this fluid in disease by Andral and Gavarret, Becquerel and Rodier, Simon, Scherer, Heller and others. The principal of the classes, with the alterations of the blood, are as follows:

*Hyperinosis.*—Diseases in which the fibrine is in excess. Its proportion in some of these cases rises to 5, 6 and even 9 parts in the 1000. The amount of corpuscles is also diminished. There is usually a considerable buffy coat in the blood after standing.

To this class belong the phlogoses, or sthenic inflammatory diseases, and especially those of the chest.

*Hypinosis.*—Diseases in which the fibrine is deficient in amount, the blood sometimes scarcely coagulating when drawn. The globules and albumen are also deficient and the fat in excess. Typhus and typhoid diseases, with severe intermittents and remittents, belong to this class.

*Spanæmia—Poor Blood.*—This is found in anæmia, cachexies, cancer, chlorosis and scurvy. In this class of diseases the solids of the blood often fall to one half, and there is a diminution of all its components. According to Heller, the fibrine is not always diminished in cancer, but in excess, indicating febrile disturbance as well as cachexy.

*Uræmia—Urea in the Blood.*—A minute amount of this body is probably a proper constituent of the extractive matters of blood, but in some diseases attended with diminution of the urinary secretion, the urea accumulates. This is particularly the case in Asiatic cholera and albuminuria or Bright's disease. Dr. O'Shaughnessy detected as much as 0.14 per cent. of urea in the blood of cholera. In febrile diseases accompanied with diminished secretion of urine, urea also accumulates in the blood.

*Mellitæmia—Sugar in the Blood.*—The blood, according to

Majendie, contains sugar (*glucose*) after amylaceous food, but it soon disappears, and is not excreted by the kidneys, but consumed in the process of respiration. But in true diabetes, sugar is found as a diseased product, and in great amount; Simon has obtained 0.25 per cent. of sugar in one case, about two hours after a hearty meal; and Rees 1.8 per cent. The sugar in diabetic urine is not always sweet, there being two varieties of the disease, *Diabetes mellitus* and *D. insipidus*; in the latter the excretion is not sweet, but it answers to the tests for glucose. (See page 243.)

*Cholæmia—Bile pigment in the blood.*—Jaundice, and all diseases of a functional, or organic nature, affecting the liver and diminishing its secretion, cause an accumulation of biliphæin or bile pigment in the blood. It is the function of the liver to separate this effete matter, and if it becomes incapable of discharging this important duty, the coloring matter accumulates in the blood and stains all the secretions. It does not appear that the biliary fats, except cholesterine, accumulate in the blood, but they have been found in the urine by Simon, who remarks that their separation is probably too rapid to allow of the detection of any amount in the circulating fluid.

In a very interesting case of jaundice, published by Simon, the serum of the blood was almost black, the amount of fibrine less than usual, the fat increased in quantity, and the corpuscles rather diminished. The yellow coloring matter of the blood and bile (*hæmaphæin* and *biliphæin*) amounted to upwards of .26 per cent. The extractive matters were also in excess. In a case of organic disease of the liver with obliteration of the ductus communis choledochus falling under my notice, the serum of the blood, the urine and perspiration were deep brown, but the serum contained no biliary matter except the biliphæin.

*Piærhæmia—Fat in the blood.*—The fatty matters of the blood exist in combination or saponified, and not in the state of globules, but in many diseases the serum is whitish, and invaded by fat globules, which are readily detected under the microscope. Fat globules are spherical, not nucleated, and present a bright clear centre with a well defined black margin. Milky serum has been detected in diabetes, pneumonia, cholera, jaundice, dropsy and nephritis. It has also been seen by Dr. Lion in a case of mammary abscess.

Fat exists in the blood in excess, but not necessarily in the state of globules, in hepatitis and most functional diseases of the liver, in pneumonia, phthisis pulmonalis and most diseases of the lungs. These two organs, the liver and lungs, preside over the process of calorification, and regulate the consumption of fatty

matters, and if either be diseased, the fat accumulates in the blood •and the organs themselves.

*Pyohæmia—Pus in the blood.*—Pus has been found in the blood in many inflammatory diseases in small quantities, but it is present in large quantities in hectic and phlebitis. The pus is detected by the granulated figure of the globules, by their size, and the existence of several nuclei; they have also a tendency to adhere in groups of two, three, five or more.

Donné proposes to test blood for the presence of pus by the addition of ammonia. If this reagent be applied to healthy blood, it forms a clear fluid, but if pus be present even in small quantity, the fluid becomes thready, or even ropy, and may be drawn out between the fingers.

*Animalcules* have also been detected in the blood by Dr. Goodfellow, Mr. Bushman and others, in peculiar cases.

**THE MENSTRUAL SECRETION.**—This secretion is less modified than any other; it presents a composition resembling blood, but contains too little fibrine to coagulate; its salts are also in excess, and it has an acid reaction. The following analysis is from Simon:

Water	-	-	-	-	-	785.00
Solids	-	-	-	-	-	215.00
						<hr/>
Albumen	-	-	-	-	-	76.54
Fat	-	-	-	-	-	2.58
Globules	-	-	-	-	-	120.40
Extractive and saline matters	-	-	-	-	-	8.60

Denis has, however, detected .05 per cent. of fibrine and only half the amount of corpuscles, hence this secretion varies with the individual and with health.

*Blood in Pregnancy.*—Becquerel and Rodier have published an interesting series of analyses of the blood of nine pregnant women. From these it appears, that this state exercises a considerable influence on the blood. Its density is increased, along with the amount of fibrine and fat, whilst it is impoverished in albumen and corpuscles. This indicates that the albumen is extracted to feed the fœtus.

**THE EFFECT OF VENESECTION ON THE BLOOD.**—At first, we would infer, that venesection acts by diminishing the constituents of the blood equally, but this is not exactly the case, the globules and water being more affected than any other portion of the fluid. This arises from the fact that the globules are confined to the larger vessels of the body, and are absent in the greater portion of the capillaries; and secondly, that the proportion of water can be readily recruited by absorption from the surrounding tissues, whereas the albumen and fibrine cannot,



The effects of repeated bleedings are also shown in the following analyses of Becquerel and Rodier. In the hundred parts of the blood, there were

		1st V. S.		2d V. S.		3d V. S.
Water	-	79.30	-	80.80	-	82.40
Solids	-	20.70	-	19.20	-	17.60
<hr/>						
Fibrine	-	0.35	-	0.38	-	0.34
Albumen	-	6.50	-	6.30	-	6.40
Globules	-	12.99	-	11.60	-	9.90

## § 2. RESPIRATION, CALORIFICATION, AND NUTRITION.

In this section we propose, in a brief manner, to discuss the uses of the blood. The chief of these are expressed by the three words of the heading; its office is to sustain respiration, by which two important purposes are accomplished—1st, the complete metamorphosis of the fluid, by which it is fitted to nourish the system; and secondly, calorification or the generation of a certain degree of heat, which is essential to the maintenance of chemical action in the body. Hence, respiration stands in the relation of a cause, and calorification and nutrition as effects.

RESPIRATION consists in the regulated admission of oxygen into the blood, and separation of carbonic acid, whereby dark venous blood acquires the arterial tint. These changes occur in the capillaries of the lungs. The air cells contain a mixture of gases derived from the atmosphere, from which oxygen is absorbed by the moist mucous membrane, and transferred to the pulmonary capillaries. At the same time, and in virtue of the universal law, that gases and vapors act as voids towards each other, a portion of the free carbonic acid of venous blood, and a part of the moisture of the cell walls, rise into the air of the cells, and thus a mixture, containing a deficiency of oxygen and an excess of carbonic acid and water, and called the respired air, is formed and thrown out of the lungs during expiration.

Expired air differs from atmospheric air, in containing about 4.3 per cent. of carbonic acid, and a deficiency of rather more oxygen; it also contains an addition of about 0.35 per cent. of nitrogen. It appears from the experiments of Brunner and Valentin, that the ration between the carbonic acid exhaled and oxygen absorbed, is as 1 to 1.175, or the same as their respective diffusive volumes; so that this is a physical phenomenon. As much as 117.5 cubic inches of oxygen are, therefore, admitted into the blood for every 100 cubic inches it gives out. This excess of oxygen is employed in changing other bodies besides carbon into oxides.

The amount of air changed in the lungs, differs from several



causes, as the capacity of this organ, the time of life, and the degree of activity. The average capacity of the lungs is 118 cubic inches; and the amount of air changed at each inspiration 15 cubic inches, but this may, in a large active man, increase to 25 cubic inches. According to this calculation, about 500,000 cubic inches are changed during the 24 hours. Of this quantity, about 30,000 cubic inches of the air expired will be carbonic acid, containing from 12 to 13 ounces of solid carbon.

But the hourly amount of carbonic acid expired, or the number of respirations differs to a considerable extent, according to the activity of the body, and in disease. We are indebted for an amount of highly interesting matter on this topic, to the labors of Andral and Gavarret, Brunner and Valentin, and Scharling.

From these it appears that the consumption of oxygen and production of carbonic acid increases from infancy to mature life—thus, in the male sex at 8 years of age, about 67 grains of carbon are exhaled per hour; this quantity rises to 126 grs. at 12 years; 166 grs. at 20 years, and fluctuates between 169 and 217 during mature life; falling, after 60 years, to 147 grs., and being, between 76 and 100 years, reduced as low as 90 grs. Thus the quantity rises up to the 45th or the 50th year, and afterwards diminishes with the strength.

Andral and Gavarret found the amount of carbon exhaled by the female at corresponding ages, less than in the male. From 16 years to 45, the amount is seldom upwards of 100 grs. per hour. There is a peculiarity in respect to menstruation; during this period the amount expired falls, seldom attaining 95 grs., but during pregnancy it rises to 125, and after the cessation of the catamenia, it also increases to 120 and upwards. When it is remembered how much fatty matter is lost from the female system by the menses, these results will not appear surprising.

Muscular development and activity have an equally striking influence over the amount of expired carbonic acid. Andral and Gavarret measured the amount of carbon expired by men of different strength, and found in one case at the age of 26, a difference between an athletic and spare man of 217 grs., and 169.4 grs. per hour. In another examination, a powerful man of 60 years expired 209 grs., a strong man at 54 years, 163.2 grs., and a slight man of 45 years, only 132.4 grains.

The influence of rest and exercise has been observed by Scharling and Hoffmann. A man, 31 years of age, whilst fasting, exhaled 145 grains of carbon; after breakfast and a walk, 190 grains, and whilst asleep, 100 grains. Similar results were reproduced in several instances with persons of different ages and sexes. Fasting, cold, sleep and rest, diminish the consumption of materials in the body, and bring down the number of respirations or amount

of carbon exhaled. If intense cold be allowed to act with rest, the respirations become finally reduced to nothing, and death arises from asphyxia—the blood being no longer aerated, congestions in the head and lungs supervene.

On the other hand, it is only necessary to count the respirations during active exertion, especially walking or running, to perceive that a very much larger amount of oxygen enters the system. In some experiments made by myself, the number of respirations were as follows: during sleep, from 10 to 11 per minute; at rest, sitting, 14 to 15; during a slow walk, 19 to 20; during fast walking, 22 to 25; when running with speed, 36 per minute. The increase during exercise, was also found to be proportionate to the rate of walking. Indeed, to sustain muscular exertion of any kind, the supply of oxygen to the system must be increased; for the increased force depends on the action of the aerated blood on the tissues.

*In disease*, the amount of carbon exhaled is subject to great variations; but unfortunately, sufficient attention has not been paid to this topic. The number of respirations afford us a good index of this change; and it is well known, that these increase in active fevers, and diminish in asthenic and cachectic diseases.

The proportion of carbonic acid in the expired air, also appears to be modified by disease. Dr. McGregor found, that the expired air of a person ill of confluent small pox, contained as much as 8 per cent., instead of 4, of carbonic acid. During the eruptive fever of measles, it is also said to amount to nearly 5 per cent. In skin diseases attended with great constitutional derangement, the amount also appears to increase. According to Dr. Malcolm, the amount of carbonic acid exhaled in the hour, is diminished in typhus.

*Medicines affect the number of respirations.*—The class of general stimulants produce an increase in the number of respirations; some of them, however, act by exciting the nerves of respiration, and thus expedite the play of the muscles; whilst others, as alcohol, ether and allied bodies, produce the effect by hastening the capillary circulation. Sedatives, on the other hand, reduce the number of respirations, either directly or indirectly, as explained above, and thus bring about that state of the system which is naturally connected with sleep or rest.

Protoxide of nitrogen, or air mixed with a small quantity of oxygen, increases the number of respirations, and by permeating the body with a highly oxygenized blood, excites the functions of the muscular and nervous system. On the other hand, any means which diminish the number of respirations, or reduce the amount of oxygen entering the blood, also diminish muscular and nervous activity, and induce sleep, congestions, and, if in excess, death

from asphyxia. The inhalation of ether, chloroform, carbonic acid or other mephitic vapors, acts in this way, and brings about asphyxia, by the act of diminishing or excluding the normal supply of oxygen to the blood.

*Effects of respiration.*—The carbonic acid which passes out from the lungs, was suspended in the venous blood of the capillaries, where it had accumulated from all parts of the body. An opinion has prevailed that this agent is combined with the iron of the blood corpuscles, which was said to exist as carbonate of iron in venous blood. But this is mere hypothesis, for the hæmatin contains metallic iron, and not an oxide; and secondly, the amount of oxygen entering the blood would not follow the law of diffusion, as proved by Brunner and Valentin, if the gas were in a combined state. Hence, one effect of the aeration of the blood is to remove a quantity of carbonic acid suspended therein, and which, by its presence, renders this fluid unfit for nutrition.

The oxygen which enters from the lungs, revives the power of the circulating fluid. It imparts to it a rich crimson color, and endows it with chemical qualities, entirely different from those of venous or deoxydized blood. The gas is undoubtedly at first absorbed by the fluid, but it cannot remain in this state long, for there exist in the blood several bodies, which have a powerful affinity for it.

Of these, the chief are fatty matters and fibrine. Indeed the affinity of moist fibrine for oxygen is remarkable, for if a small amount be exposed to the air, it becomes rapidly oxydized, and if introduced into the peroxide of hydrogen, that fluid is decomposed by the affinity of the fibrine for its oxygen. That it absorbs oxygen in the blood, and that the corpuscles do not perform this office is readily shown, for if oxygen be passed through venous blood it is reddened, but if the blood be deprived of its fibrine or defibrinated, the oxygen does not produce a change of color, nor is it absorbed to the same extent as in the preceding case.

We may, therefore, with Mulder, regard the fibrine of the blood as the *carrier of oxygen*. By this oxydation it becomes converted into the binoxide and tritoxide of proteine, in some degree; its phosphorus and sulphur suffering oxydation, and being converted into phosphoric and sulphuric acids, which combine with soda and other bases in the blood. By this temporary contrivance, oxygen is borne to every part of the body. It is not so united with the fibrine, as to refuse the solicitations of other agents, which have a stronger affinity for it, and is therefore gradually liberated in the course of the circulation, and especially in the capillaries.

Mulder conceives that the oxides of proteine, especially the insoluble binoxide, is moulded about the blood corpuscles, increasing

their thickness and refracting power, and producing the change of color. Another explanation may be given of this change. It has been shown in the article *Hæmatin* (page 293), that the difference of figure of the corpuscles depends upon the amount of water in the blood. In the lungs a large quantity of water is exhaled from the blood, and the saline matters therefore rather increased in their proportionate amount; a result of this change will be endosmosis from the disks, and the production of the biconcave figure. The proteine compounds have also a strong affinity for water, and will conspire to bring about the same result.

That the oxides of proteine are really formed, is proved by the well known fact, that when the respirations are augmented in disease, as in inflammatory fevers, there is formed an inflammatory crust or buffy coat, which is composed of these oxides. Again, by reference to the composition of mucus, arterial membrane and other tissues (p. 333), it will be seen that the principal constituents of the body are hydrated oxides of proteine, or in other words, substances nearly allied to the products of the action of oxygen on venous blood. In this view, the aeration of the blood is a preliminary stage in nutrition; and hence the necessity for respiration in the repair of the tissues of the body becomes strikingly apparent.

But in the course of the circulation, some portion of the oxygen, attached to the fibrine, leaves it to oxydize or combine with other bodies. That this is the case, appears from several considerations: 1. The materials passing from the blood for the repair of parts is not so highly oxydized as the binoxide and tritoxide of proteine; 2. There are formed several oxides in the course of the circulation, especially carbonic acid ( $\text{CO}_2$ ), and the phosphoric and sulphuric acids, which must derive their oxygen in part from the inhaled gas; 3. The animal heat, which sustains the body, is produced in the capillaries of every part of the system, and is the result of the oxydation of fatty and other matters in the blood and tissues.

The difference produced by respiration, between venous and arterial blood, therefore resolves itself into three prominent circumstances.

1st. Oxygen causes the proteine compounds to take on a new form preliminary to their precipitation in the tissues of the body, for the repair of parts.

2d. A portion of the oxygen is expended in resolving fatty and the effete matters of the tissue into carbonic acid, and other oxides, for the maintenance of the animal heat; and the preparation of the effete matters, previous to their separation as excretions.

3d. A consequence of the foregoing actions of the oxygen of arterial blood is an increase of the affinity of this fluid, as compared with venous blood, for the tissues of the body—in conse-



quence of the close chemical relations existing between them and oxygen, and which constitute the chief cause of its circulation in the capillaries of the system.

Other differences undoubtedly exist, but their history is obscure. The power of the blood to assimilate chyle, the metamorphoses whereby globulin, hæmatin, the globules and phosphorized fats are brought into existence, are, no doubt, connected with the presence of this extraordinary agent; but these are effects that can be merely surmised. It is, however, to be remarked, that in nearly all the cases of pure catalytic action, by the presence of platinum, condensed oxygen is the active body. In the blood this agent is present; it is, moreover, condensed by the fibrine, and there are presented to it bodies, such as the fats, which are extremely prone to change by oxydation. Fibrine, moreover, acts catalytically when presented to the peroxide of hydrogen; and the oxides of proteine are the active ferments of organic chemistry.

**CALORIFICATION**—*the process whereby the constant heat of the body, about 98.6° F., is sustained.*—The principal seat of this function are the capillaries, and the fluid in which it takes place is arterial blood: for this possesses a temperature higher than that of other parts of the body. From the phenomena of inflammation, we also conclude that the action whereby heat is produced takes place chiefly in the capillaries.

In all cases of combustion occurring under ordinary circumstances, and in which the organic matters of animals or plants constitute the fuel, oxygen is absorbed. Or, in other words, for the production of heat, oxydation must occur. The oxygen attached to the proteine bodies in arterial blood, is able to follow the solicitations of stronger chemical affinities, and may, therefore, be regarded as partially free. Whatever bodies have a powerful affinity for this agent, will be oxydized; and we know that carbonic acid and water are, in this case, as in the ordinary burning of many organic bodies, the products of combustion, within the body.

Excluding the proteine bodies, the fatty and extractive matters of blood are the only ones liable to be acted on by the oxygen. Of these, the fatty matters have a powerful affinity for this agent, and the extractive bodies are not known to have any; moreover, the latter are not understood to be connected with calorification, in any particular, whereas the fatty matters are so.

That *the fatty matters of the blood constitute one principal source of animal heat*, is apparent from the following considerations. Non-azotized food, in passing into the blood, becomes converted into fat. The proportion of this kind of aliment instinctively demanded by the system, increases with the external cold; and in the arctic regions, fats and oils compose the greater part of



the food of the inhabitants. The veins absorb fatty matters, and venous blood is plentifully recruited therewith from the chyle and lymph; but the proportion does not greatly increase in health, and diminishes in the arteries. Yet notwithstanding that many ounces of fatty matters enter the circulation daily, the generality of mankind do not, in health, rapidly increase in fatness; hence, it is not as a general thing deposited, but consumed in the body. On the other hand, if animals, as pigs, be fed with linseed cake or corn, rich in oil and kept perfectly still, and in a warm situation, the fatty matters cannot be consumed, from the want of a sufficient supply of oxygen and are deposited in their bodies. But on the other hand active animals, especially in cold weather, do not rapidly fatten.

The liver and lungs are interested in the process of calorification; the former prepares, in some measure, the fatty matters, and the second, by the introduction of oxygen in respiration, regulates their consumption. If the lungs be diseased, especially in phthisis pulmonalis, and too little oxygen be admitted, the fat of the blood becomes deposited in the tissue of this organ, and to such an extent as to constitute from thirty to fifty per cent. of its solid portion. The liver likewise suffers, fat being deposited in this viscus whenever the respirations are reduced, or some substitute for fat is introduced into the system to act on the arterial oxygen, as alcohol.

Liver diseases often arise in tropical climates among strangers, from incautious diet; accustomed to the use of large amounts of butter and good meats, they overlook the influence of climate, and introduce into their bodies amounts of fat which cannot be consumed by the process of calorification, and are, therefore, deposited in the liver, and serve to embarrass the functions of that organ. Whilst such persons do not restrict their diet, they are compelled to abstain from exercise, and therefore introduce much less oxygen into their system than in northern positions. On the other hand, the natives content themselves with fruits and vegetables, eating little meat and fatty bodies, and are exempt from hepatic diseases.

The process of fattening geese, for the epicure, by which the *foie gras* of the French is obtained, also satisfies us that the principal substances consumed in the generation of the animal heat are fatty bodies. In this case geese are crammed with fatty food, fastened down before a hot fire, and kept without water. The heat and rest disposes them to sleep, the respirations become few and laborious, and the fat introduced into the system not being consumed, is stored in the liver, increasing the weight of that viscus manifold in a few weeks.

In disease we observe evidences of the same fact. In fevers a

high temperature is sustained, without the introduction of food into the system, the respirations are increased, and the first appearance of waste to sustain the fire of the fever, is in the accumulations of fat. In starvation the fat disappears first ; and before the consumption of the muscular portions of the frame, the fats of the brain fall before the assaults of the oxygen of the arterial blood. Delirium occurs as a consequence, long before death closes the scene.

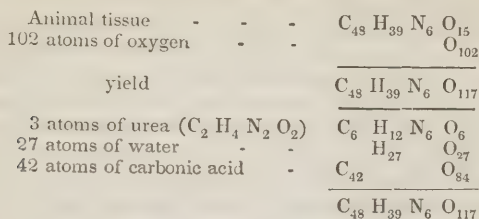
The heat, which becomes sensible in the incubation of the egg, arises from the oxydation of the fat of the yolk, which diminishes as the process advances. Again, in hybernation, we find that the animals retire in the winter loaded with fat, and in the spring appear in a state of emaciation. As during this period respiration is the only function not suspended, it is clear that the oxygen introduced acts (perhaps exclusively) on the fat.

According to the older writers, *the globules* of the blood are connected with the production of heat. It is true that in anæmia and chlorosis, diseases attended by a deficiency in blood corpuscles, the animal heat is somewhat less, but by no means in proportion to their reduction, which often exceeds two-thirds. Again, in arctic regions, there is no material increase in the proportion of globules, whilst the amount of heat generated, to resist the cold, is very much greater than in temperate localities. More oxygen and fat are introduced into the body ; but there is not any increase of blood globules.

Dr. G. O. Rees announces that the blood globules contain a phosphorized fat, which is consumed by the oxygen admitted by the lungs, and thus serves to generate heat. But the phosphorized fat of the blood is in too minute a quantity to supply so much heat, and it is difficult to perceive in what way several ounces of this body can be procured in the day ; for ordinary fat and the oils of vegetables, contain no phosphorus. A minute proportion of phosphorus, and perhaps sulphur, are unquestionably oxydized in the blood, but they afford an inconsiderable supply of heat.

*Besides the Consumption of Fatty Matters, other sources of Heat exist.*—The body is a constant scene of waste and repair ; as one portion of tissue is repaired by the nutritious exudation of the blood from the capillaries, another portion is broken down and returned to the blood. The re-entering substances suffer oxydation at the time of their disorganization, and pass through a series of changes, which ultimately eventuate in the production of carbonic acid, water and urea, all of them oxydized products. Disregarding the intermediate steps, of which we know little, this change may be made to appear by the following diagram. It has been said that muscle, nerve, and tissue, taken together as in a piece of beef, have a composition identical with that of the blood.

If we add oxygen to the formula, representing these mixed bodies, it is found to yield the above products. Thus :



The products of this oxydation are discharged chiefly by the kidneys and lungs. They cannot be formed without the evolution of heat. Hence, in the separation of effete matters from the body, a process which is continually going on, and produces the secretion of urine, and the exhalation of carbonic acid and water from the lungs and skin, a considerable amount of heat is developed. This heat, conspiring with that obtained by the direct consumption of fatty matters, constitute the main supply of the body.

Heat is evolved in the action of the muscles, and is also found to diminish in a remarkable manner upon the division of the pneumogastric and other nerves. Hence it has been inferred that the nerves create heat, but this is absurd, for the nerves convey a force, and heat is a second force; therefore, to urge that one force creates another without the intervention of matter, is to argue that nothing creates something. Heat can no more be created by the body, without fuel, than it can by the furnace. It may be regulated by the nervous system, in diminishing or increasing the respirations, or diverting large amounts of blood to particular organs, but it cannot be produced without the change of some substance by oxydation.

*The amount of heat is rigorously as the oxygen consumed.*  
 —Whatever is oxydized in the body gives out heat, and the amount of change depends exclusively on the proportion of the oxygen. With an increase in the respirations, the proportion is augmented. We therefore find that the temperature of animals bears a close relation to the numbers of their respirations. The number of respirations of the pigeon, according to Prevost and Dumas, is 34 in a minute, and its temperature  $107.6^{\circ}$  F.; in the cat the heat is  $101.3^{\circ}$ , and the respirations 24; whereas, in man, it is  $98.6^{\circ}$  F., and the respirations average 18 per minute.

The amount of oxygen entering the system is subject to perpetual change, it is as the respirations, and these vary from 10 to 40 in a minute. But under ordinary circumstances, it may be allowed that 32 ounces are consumed daily.

We may proceed to calculate how much heat this amount of oxygen would generate in combining with the tissues of the body, and in this way prove that it will be sufficient to sustain the animal heat. For this purpose it is, however, preferable to calculate the amount of heat produced by the combustion of the carbon; as the proportion entering the system has been ascertained more directly, by analyzing the food and excretions.

The amount of carbon introduced by food into the circulation daily, at a moderate temperature, in hard working men is equal to 13.9 ounces (Liebig), in men of comparative leisure about 11 ounces, and in those who are of less than ordinary stature, and who use little exertion, especially females, from 8 to 6 oz. Now, according to the experiments of Despetz, the heat yielded in the combustion of one ounce of carbon is capable of elevating 78.15 ounces of water from 32° to 212° F., or 180 degrees; or  $78.15 + 180 = 258.15$  equals 14067 degrees of heat. Hence, the 13.9 ounces of carbon consumed in the metamorphoses of the body generate  $13.9 \times 14067 = 195531.3$  degrees of heat. This, according to Liebig, is sufficient to heat 184.3 lbs. of water from 32° to 98.3° F., or the temperature of the body, and can evaporate 3 lbs. of water, in the form of insensible perspiration, during the day, and allow a large amount of heat to remain to sustain the body from the effects of cooling by radiation.

It will be remembered that, besides the amount of carbon, a considerable quantity of hydrogen is also oxydized; hence this, with the foregoing, will constitute an abundant source of animal heat.

**NUTRITION.**—By the introduction of oxygen into the blood, it becomes capable of repairing the tissues changed by the incessant wear of the machine. Nutrition takes place by the exudation of the albuminous portions of the blood, previously modified by oxygen, through the walls of the capillaries, into the cells of the basement tissue of all parts of the body. By this afflux of blastema, new cells are generated and prepared to take the place of those which have been destroyed by chemical action. This is the ordinary process of nutrition in the healthy parts of the body, but in some cases the blastema may be exuded in the amorphous state.

In mature life the amount of substance passing out of the blood vessels is exactly counterbalanced by an amount of effete matter returning in the opposite direction. The passage outwards, or *exosmose*, is met by a passage inwards, or *endosmose*, of fluid to the same amount. Thus there is attained an accurate balance between the materials of waste and repair, and the weight of the body remains constant from year to year. But during youth nutrition is in advance of waste, and growth occurs. In



persons of great activity and in disease, waste occasionally exceeds repair. Every muscular or mental effort is accompanied with the oxydation of parts and waste of tissues, and if these be not restored, by rest and generous diet, debility ensues.

The matters returning to the blood constitute a portion of its extractive bodies, which are effete forms of proteine; but besides them, urea, carbonic acid and water are probably admitted—for it is scarcely possible that all the changes of oxydation occur in the blood and no portion in the tissues.

These currents out of, and into the capillary vessels, are a result of chemical affinities. The chief of which, according to Liebig, is the acid nature of the fluid external to the blood and the alkaline reaction of the blood itself. Other causes are also calculated to set up such a current, as the difference of density in the inner and outer fluid, the excess of oxygen in the arterial blood, and the amount of carbonic acid in the fluid of the tissues.

Hence, the exudation of the blastema, cell-food, or nutriment destined to repair the tissues, is a result of capillary action and obeys its laws. The further consideration of endosmosis and capillary action will be resumed in the next chapter.

The following illustration from Liebig sets forth the relations of nutrition to waste in a striking manner. A serpent kept for some time (weeks) without food, and then fed on a goat, rabbit, or bird, expels from the body, apparently unchanged by the intestines, the hair, hoofs, horns, feathers or bones of the devoured animal; exhales carbonic acid and water; and evacuates by the urinary passages urate of ammonia. The urate of ammonia answers in serpents to the urea of mammals, and has nearly the same composition.

The serpent after a time regains its original weight and no part of the prey is discoverable in its tissues. Let us analyze this simple case of nutrition. The muscles, blood and fatty matters of the prey contained substances in which there were 8 atoms of carbon to 1 of nitrogen. The urate of ammonia containing all the nitrogen of the food has but 2 equivalents of carbon to 1 of nitrogen; hence there is an excess of 6 atoms of carbon which does not pass off by the urine, but which passes off by the lungs as carbonic acid, having combined with the oxygen admitted by respiration.

In the lion and all carnivora the result is the same, but the consumption is more rapid. In man and animals which live on mixed food, the proportion of carbon to the nitrogen changes with the proportion of fatty and amylaceous bodies, but the urea, which contains nearly, if not all the nitrogen of the food, depends rigorously on the azotized matters they consume. Under ordinary circumstances a man evacuates 231 grains, or nearly half an



ounce of nitrogen in urea and uric acid during the day, and this is the proportion in the meats and proteine bodies he usually consumes.

### § 3. SECRETION.

It has been explained that in the act of nutrition the blood loses a portion of its normal components, and acquires a certain amount of effete matters. These render the circulating fluid impure and unfit to sustain life, and must be thrown out of it. To this end the secretions are necessary, and principally, the urine, the separation of carbonic acid by the lungs and skin, and the bile.

The kidneys separate the whole, or nearly the whole, of the effete nitrogen bodies in the form of urea and uric acid, in the carnivora, and urate of ammonia, in birds and reptiles. They remove also the saline matters which are in excess, or which are the products of oxydation and metamorphosis in the body, such as the phosphate of ammonia. This secretion will be examined at length in another part of the work.

The secretion from the skin has already been partially treated of, in the chapter on heat, page 37. It consists nearly entirely of water, but carbonic acid, lactic acid and a minute amount of phosphates and urea are also separated. The pure secretion, the insensible perspiration, is mixed with the sebaceous matter of the sebaceous glands, the office of which is to render the skin soft and pliable. The latter can scarcely be called a secretion, for it is an essential part of the cuticular tissue, and fatty matter scarcely changed, with epithelium scales and a small amount of lactate of lime and soda. The chief office of the insensible perspiration is to equilibrate the heat produced by chemical changes within the body.

From the lungs, carbonic acid is excreted; here also a considerable amount of water is evolved in the state of vapor, which serves to refrigerate the system.

*The secretion of bile* is different from the foregoing; this fluid is only partly excrementitious, the greater portion of its solids being returned into the system along with the chyle and serving the same purpose as other fatty matters. The liver is set in the way of the entrance into the blood, of much of the nutritious matter of the food. The portal veins are active in absorbing fatty matters, as well as other substances, from the stomach and intestines, which they convey to the liver for assimilation. Hence, this organ not only secretes from the blood, but also assimilates matter for the reparation of this fluid.

Portal blood, from which bile is prepared, contains twice as much fat as arterial blood, and this is separated by the liver.

The tubuli of this organ prepare a mucus, rich in soda, which serves to attract a considerable portion of the fatty matters, from the minute branches of the portal veins. Union occurs between these bodies, and there is formed a compound of a fatty acid (*the choleic*) with soda, which is the principal constituent of the secretion. But as choleic acid differs from the fats of food, they must undergo in the blood or by the action of the biliary mucus a catalytic change which is of the nature of assimilation.

Simultaneously with the formation of this body, cholesterine and coloring matters pass from the blood, and thus the bile is formed. This fluid, therefore, consists of choleic acid combined with the soda (*choline-soda, bilate of soda, choleate of soda*) of the hepatic mucus, of cholesterine, and coloring matter (*biliphæin*). Of these the choleate of soda is the characteristic body.

Choleic acid (*bilic acid, bilifellinic acid*) resembles bile, purified by the separation of the coloring matter, by animal charcoal; it is a yellowish, brittle body, resembling gum Arabic, of an intensely bitter taste and soluble in water and alcohol, but not in ether. Artificially combined with soda, it acquires all the characteristics of bile, and forms a yellowish soap, which lathers with water, has an alkaline reaction and a bitter nauseous taste. Its formula, according to Liebig, is  $C_{76}H_{66}N_2O_{22}$ .

By the action of strong acids or alkalies, choleic acid is changed into a number of bodies which do not, however, exist in bile; such as the cholic and choloidic acids, &c. The bile in disease often develops a large amount of cholesterine, a non-saponifiable fat, like spermaceti; and a large amount of modified coloring matter called *biliverdin*, and found by Berzelius to be identical with chlorophyll. These form the two principal ingredients of biliary calculi; and exist separately, or may be combined. They would appear to be products of the mal-assimilation of the liver; for it is probable that choleic acid is a compound of the effete coloring matter of the blood, hæmaphæin, with fatty bodies, which are resolvable into cholesterine. The nitrogen existing in this body shows that some modified proteine body has participated in its formation.

The amount of bile produced daily is considerable; M. Blondot found that 10 to 12 drachms were discharged daily from the liver of a dog. In this case a fistulous opening into the gall-bladder had been made, and the ductus communis choledochus tied.

Of this 20 per cent. was solid matter, nine-tenths of which was the choleate of soda (*bilin or bilate of soda* of authors). This chemist observed that the proportion of bile was increased when fat, sugar, or amylaceous matters were given to the animal. The secretion also served to stimulate the peristaltic action of the

bowels, and was carefully licked up by the animal. The animal at first was emaciated, and continued so as long as he licked up the bile, but this being hindered, his bowels became torpid, the stools white, and he grew fat. M. Blondot observed these facts in two dogs, and infers that the bile is excrementitious and of no service in the economy, a view opposed to that of all chemists and of Schwann, who found in a series of similar experiments, that all the animals died from the want of the secretion. Blondot, like other chemists, was unable to detect choleic acid in the fæces of the dogs that licked up the bile, hence there is reason to believe that it was thrown back into the system, probably modified by contact with the chyle.

The presence of bile pigment (*bilipæxin*, *cholepyrrhin*) in the serum, urine or any other fluid, is readily determined by the gradual addition of nitric acid, which produces first a blue, then green, violet, red, and ultimately a yellowish-brown tint.

*Production of the Secretions.*—How are the secretions formed? In the case of the bile and the secretion from mucous surfaces, it arises from the development and separation of cells, but this is not the case with the urine or milk. The milk contains globules, but they are not cells produced by a regular basement tissue, but of the same nature as the fat globules of the chyle, or of ordinary emulsions. For if we allow an oily matter to come slowly in contact with a dilute albuminous fluid, there will be formed oil globules, the wall of which is a pellicle of albumen. This is a process altogether distinct from cytogenesis.

Urine and milk are secretions which appear to leave the blood without the elaboration of cells; and this is not at all remarkable, since the chyle undoubtedly finds entrance without this mechanism. These secretions are merely strained from the blood, and serve to separate matters existing therein.

Milk nearly resembles chyle, the principal difference being the presence of caseine in the place of albumen, and the amount of sugar. It is also liable to change from the ingestion of numerous bodies, especially volatile oils and saline matters.

The blood always contains a small amount of urea, which is the characteristic component of urine. Indeed, this secretion contains nothing which is not pre-existent in the blood, and seems to drain away from that fluid without any considerable preparation. It is remarkably altered by foreign bodies; thus the saline substances with an alkaline base, administered as medicine, are found here unchanged; so with coloring matters and many volatile oils. Large draughts of water, especially in the winter, increase the amount of the secretion.

Secretion, according to this view, is no more than the filtration

or separation of useless bodies from the blood, and is a result of capillary attraction.

The phenomenon of vicarious secretion sustains this view. We find that when the action of the liver is diminished or stopped, the coloring matter (*hæmaphæin*), which it is the duty of this organ to separate, accumulates in the blood, and is secreted by the kidneys and skin. If the secretion of milk in the female be suddenly stopped, caseine (*kiestein*) is found in the urine. Urea increases in the blood in diabetes and organic diseases of the kidney, and is discharged by the skin. The menstrual flux is also occasionally discharged in the urine, and sometimes passes off from the mucous membrane of the lungs or stomach.

But the capillary action of the glands, whereby the blood is strained of its impurities, and the secretions formed, is like the capillary action of every other part of the body, under the influence of the nerves. The secretion is, therefore, normal only when the body is in health, and disease, affecting the nervous centres, is as influential in changing the relations of the gland-capillaries to the constituents of the blood, as disease in the organ itself. Hence, we have alterations in the urine and other secretions, arising from nervous affections and general disease; and find at one time a suppression of urea, and at another an evacuation of albumen.

#### CONCLUSION ON THE BLOOD.

From the foregoing, the blood is to be regarded as the great source of nourishment, and the receptacle of the effete matters of the tissues. It is at once the means of sustenance for the body, and the stream into which the substances which have suffered decomposition and organic death are cast, to be separated by the liver, lungs, skin and kidneys. The chyle and lymph undergoing assimilation in it, and being aerated by respiration, become fitted to repair the tissues, and the muscular and nervous framework.

The refuse of the body, which has served its purpose in generating muscular power or nervous activity, returned to it, is subjected to further change and prepared to leave the system as urea, carbonic acid and water; substances which become resolved in the air into carbonate of ammonia, carbonic acid and water. Thus the animal machine breaks down the complex amylaceous and proteinous bodies of the vegetable, acting on them by eremacausis or oxydation, and restoring them to the mineral world.

But the heat and light, which have acted in the plant, to bring together the products of vegetation, are not lost in the body. If



the animal destroys organic matters, and converts them into air and water, with a little saline matter, it economizes their latent forces. Heat is evolved in calorification, and an imponderable closely analogous to electricity, which we call the nervous power, is developed. It has been shown, that the muscular and active man consumes more oxygen, than the spare and inactive; and this that more organic matter may be changed and power produced.

As Matteucci (page 122) found, that the activity of the musculo-cutaneous current in animals, depends upon the supply of blood, so we know, that every increase of power, whether of the nervous masses or the muscles, is associated with an increased capillary circulation in the part—with increased oxydation and waste. The power generated is rigorously in proportion to the oxydation of the muscle or brain. Whenever we employ means, as by the inhalation of protoxide of nitrogen, to super-oxydize the blood, excessive action results, and as we diminish the supply of this agent, the powers of life flag, and become extinguished, with the final loss of oxygen.

The phenomena, termed by us life, flow from the changes going on in the blood and tissues. Each molecule of fat that is oxydized gives out its proportional of vital heat. Each atom of the fat acid of the brain (*cerebric acid*) that falls before the affinities of oxygen, throws out a force that circulates in the nerves; whilst the muscular tissue responds to the influence of the same element, by the production of movement.

Life is the resultant of regulated chemical changes, which owe their peculiarity, to the framework solely. Many of the alterations impressed upon the proteine and fat compounds can be imitated in the laboratory, but we perceive heat, light and electricity only as the accompanying phenomena. The evolution of true cellules, which make up the body, is the characteristic of life. It is the laboratory which is peculiar, not the agent of change, for this is purely chemical.

Death results, when the generation of cellules comes to an end, or when their food, derived from the blood, is radically altered. If the metamorphoses arising from respiration be not perfected, if the sources of supply be drained, or if disease affects the current, the machine comes to a stand, and its delicate and complicated parts lose their office. The stern laws of the inorganic world rule in the stead of the cellular operations of the organic kingdom, and the body passes to the air and the earth from which it was derived.



## THE CAPILLARY FORCE.

*Synonymes.* Endosmosis and Exosmosis; Penetration of tissues.

HAVING presented a view of the composition of blood, and the principal nutritious fluids, the question arises how are these conveyed to the cellules, which they nourish? Or, in other words, what causes the circulation of the nutritious juices, the penetration of chyle into the system, and the separation of the secretions from the body? We answer that this arises from the capillary force, which is the active cause of the phenomena termed *endosmosis* and *exosmosis*, the penetration of tissues, and cell nutrition.

The capillary force, or capillary attraction, has been defined in the first part of this book (pp. 126 to 128), to be a species of affinity, inferior to the chemical affinity in force, but having the same electrical cause. The wetting of solids by some liquids, cases of solution, the diffusion of gases, and the admixture of liquids, where none of the disturbances characterizing chemical action (p. 128) arise, are instances of capillary affinity.

*Phenomena of the Capillary Force.*—If a piece of dry bladder, or the dry opaque cornea, be placed in water, the fluid penetrates every part, enlarging its bulk, and endowing it with a degree of transparency. This does not arise from leakage, because it takes place in opposition to gravity when the membrane is suspended, so as to touch the water at one part only. It arises from the existence of a peculiar affinity between the bodies, and is an illustration of capillary action. All fluids will not rise; if we dip these membranes into mercury, they do not become swollen by its penetration into their parts.

The illustrations here presented are not more striking than those occurring continually around us. The ascent of sap in trees, the swelling of wood when immersed in water, the solution of sugar, are all instances of this action. But the nature of capillary attraction is best studied with glass tubes. Water and many other fluids wet glass, or have a capillary affinity for it, and will rise between two planes of this material, or in tubes made of it.

The height to which water rises in a glass capillary tube, depends upon its bore, being inversely as the diameter. A tube of half an inch bore, plunged into water, will scarcely draw the fluid above its common level; but the water within the tube will exhibit a concave surface. If the tube be  $\frac{1}{50}$  of an inch, the water will rise one inch, if  $\frac{1}{100}$ th, two inches, and so forth, according to the above law.

Now, if in the place of water, we examine the action of other liquids, we find that they are not attracted in the same degree, but that each fluid rises according to its affinity for the material of the tube. Muschenbroëck determined that a glass capillary tube which would raise sulphuric acid 1.3 inch, would raise alcohol 1.8 inch; oil of turpentine, 2.56 inch; water, 3.4 inch; strong solution of ammonia, 3.6 inch; and solution of carbonate of ammonia, 4.56 inches. It will be observed that the cause of elevation is independent of specific gravity. Nor is there any chemical action in these cases. *The fluids rise because they have different capillary affinities for the glass.*

But all fluids do not rise in capillary arrangements. If a tube of glass or iron be immersed into mercury, the fluid sinks in the interior of the tube, or is repelled. If, however, we change the electrical relations of the tubes and mercury, by putting them in connection with the different poles of a galvanic battery, the fluid rises. So in every case we find that the fluid rises when the electrical relations of the two are dissimilar, and is depressed when they are similar. Hence, electricity is the cause of the movements of fluids in solids. This is further established by the fact that the two are always found in different electrical states if separated and examined. (See p. 127.)

As there exists so much difference between the affinities of dissimilar fluids, it is apparent that, when a capillary body is brought in contact with two fluids, only one of which exerts an attraction for it, or one of which exerts a greater attraction than the other, it will be affected by the one only. Thus, if water be poured on quicksilver, and a capillary arrangement, consisting of a few strands of cotton yarn let down into it, the water will rise, but not the mercury. So if oil be poured on water, and the same substance sunk into them, the oil only rises, for it has a greater affinity for the yarn than the water. In this way a capillary arrangement may be used to effect a partial separation of bodies.

If we dip a glass capillary tube into olive oil, a certain amount of the oil will rise, and if we now dip the same tube into water, this will also rise, and push the oil up before it. *Thus, movement is effected, the least attractive of two fluids being pushed forward in a tube by the more attractive, and even driven out of it.* This law holds in every case where the circumstances are similar.

*As the advance of the liquid depends on the attraction of the sides of the tube, it cannot rise higher than its upper margin, however minute it may be.* If a tube, capable of elevating oil three inches, be broken at one inch above the surface of the fluid, the oil cannot overrun the summit. But if we set fire to the oil, or cause it to be removed from the summit of the tube in this or any other case, fresh quantities will rise from below to take the

place of that carried away or decomposed, and thus a current will be established. This occurs in the common lamp; when unlighted, the wick is saturated with oil, and none overflows, but if we inflame it, however rapid the consumption, new portions of oil rise to replace those destroyed.

*Capillary action takes place in every case where the necessary chemical affinities exist.*—It is not necessary that there should be visible vessels or pores, or that there should be a fluid or solid—it occurs between two fluids, between gases, and between gases and solids or fluids. In every case, whether it be a mass of metal, a volume of gas, a fluid, or a membrane, there is an infinite number of pores or interstices existing between the ultimate particles, and into these the fluids or gases intrude. To the passage of bodies which have a chemical affinity, no opposing force exists—density, closeness of texture are as nothing; but on the other hand, a tissue, however open, which has no electrical affinity of a fluid, offers an insurmountable obstacle to its penetration. Indian rubber, which resists water, is rapidly permeated by carbonic acid, and softened by ether.

*The intensity of the capillary force is as the electrical relations of the bodies.*—When their affinity is slight, the liquid rises in a tube or permeates a tissue, but in a small degree. If it be intense, the fluid rises high in a tube, and may proceed so far as to dissolve or disintegrate the solid. In the highest state of capillary attraction, it becomes identical with the chemical force.

**APPLICATIONS OF THE PRECEDING FACTS.**—The preceding facts which are true for membranes, minerals and all bodies whatever, have a special application to the phenomena of the penetration of gases through membranes, to endosmosis and exosmosis, and the capillary circulation in animals and plants. We shall briefly consider these applications.

*The penetration of gases through membranes* takes place, however thick they may be, but is more rapid the finer the membrane. The passage is through the interstices between the atoms, and not through any obvious pores, and occurs with different rapidities for dissimilar gases. It does not follow the law of *diffusion* (page 176) in every case, for the membrane sometimes condenses the gas, and may enter into chemical union with it. The passage takes place notwithstanding pressure. Dr. Draper determined that a pressure of 450 lbs. on the square inch, did not hinder the passage of sulphuretted hydrogen through a membrane.

The introduction of oxygen into the blood, and the exhalation of carbonic acid and vapor of water in the lungs, offer illustrations of penetration in the bodies of animals. There is no difference between the passage occurring through dead or living membrane,

or through Indian rubber, water or porous minerals, except so far that these bodies do not condense gases to the same extent.

*Endosmosis and Exosmosis.*—These words were introduced by Dutrochet, to express the fact that when a bladder is filled with alcohol and immersed in water, some portion of the alcohol comes out from the bladder, and is replaced by water, which goes into the bladder. The outward current he termed exosmosis, and the inward, endosmosis. He conceived this to be a peculiar operation, and to depend upon the texture of the membrane, but it is now known to occur through the pores of mineral bodies. It is a case of the penetration of fluids.

It is regulated by a few simple laws, the principal of which are as follows:

1st. The fluids or bodies, on either side the membrane or porous system, must have capillary attraction for it.

2d. They must have an attraction for one another. If we fill a bladder with oil and immerse it in water, the passage inwards and outwards does not occur. The oil penetrates the tissue passing from the inner to the outer surface, but here all capillary attraction ceases. It cannot advance beyond the limit of the pores or interspaces of the bladder, any more than oil can flow over the wick of a lamp. To leave the membrane, it must be solicited by the exterior fluid, and combine with it by capillary action. The same holds for the water from the exterior; this passes through the thickness of the bladder, but being insoluble in oil, cannot mingle with it.

Place a solution of potash outside of the bladder of oil, or any substance with which it can combine, or for which it has an affinity, and it will pass out freely.

3d. When the fluids have an attraction for one another, and unequal affinities for the membrane, that which has the greatest passes through most rapidly. If we place strong alcohol in the bladder and water exteriorly, the latter having most affinity for the membrane, enters much more rapidly than the alcohol passes out; hence the bladder becomes distended, and will burst if completely closed. Or if we adjust a graduated tube to it, the excess of fluid rises and may be measured; such an arrangement is termed an *endosmometer*.

A thick solution of gum or sugar, or a concentrated solution of any soluble salt placed within the membrane, solicits the external water, which flows into the bladder in excess. But if the arrangement be reversed, the excess of current is in the opposite direction. In all these cases some amount of the denser fluid passes, but in less quantity than the lighter.

4th. The current inwards and outwards flows as long as there is a difference in composition or density between the fluids; the



rate diminishing as the difference lessens. The foregoing laws are also true for gases.

*Cell Nutrition.*—The access of nutriment into the cells of any part is subject to the above laws. Indeed, the growth of the cellule is a consequence of them. The bounding membrane is not an impediment to the passage of nutritious matters, which necessarily possess a considerable capillary affinity for the tissue, any more than the bladder impedes the entrance of water. The current of cell food (*cytoblastema*) will, as a general rule, flow faster into the cell than its elaborated contents escape—hence, the development of the part and its final destruction by bursting.

The basement tissue of a part lying upon the cell food and permeated by it, evolves cells which suck up like a sponge the food, expand by its introduction, and finally burst, yielding their contents as a secretion. Or they may, by absorbing oxygen with their food, as in the muscles, brain and other parts, cause a change thereon, or perform a species of digestion, converting the blastema into effete matter, and evolving electricity, or the nervous power.

The passage of albumen out of the capillaries, and the introduction of the effete fluids of the body, are obviously cases of exosmosis and endosmosis. The ascent of sap in a tree, the introduction of fluid into the veins, lacteals and lymphatics, are other instances, for these are not open vessels. They are charged with a fluid having alkaline reaction, and which has the property of soliciting fatty matters and albumen from the intestines or other parts of the body. Fill a delicate membranous tube, with a dilute solution of carbonate of soda or the alkaline tribasic phosphate of soda, and place it in an oily emulsion, and it will be found that the oil penetrates the membrane by endosmosis.

*Capillary Circulation.*—It is well known that all the functions of the body are carried on in the capillaries and not in the large vessels. The arteries nowhere enter the veins, but between them lie minute vessels or interstices, in which the arterial blood becomes changed into venous. These interstices, whether tubular or intercellular, constitute the capillary system of the body. The diameter of the vessels and spaces varies from  $\frac{1}{1500}$  to  $\frac{1}{10000}$  or less of an inch.

The plasma of the blood, the chyle, lymph and muscular fluids move in these interstices, and are altogether independent of the action of any mechanical force. The heart has no influence to control these currents, for it has no connection with the absorbent system, with the portal capillaries, nor with the interstices between the cells. The office of this organ is to regulate the circulation in the whole body and to drive the blood into the large

arteries. And this it does with a force equal to about one pound to the square inch.

The capillary circulation even in the vessels lying between the arteries and veins, is independent of the heat. The movement here is increased or diminished by local means which do not affect the central organ. If the web of a frog's foot be exposed in the field of the microscope, the white blood (plasma) of the capillaries will be seen moving leisurely, from artery to vein, and meandering among the tissues. It all takes a determinate course to the veins. If the web be touched with a drop of strong brine or alcohol, the currents rush to the spot, and a centre of inflammation is established. On the contrary, if an aqueous solution of opium be placed on it, the current becomes more languid and retires from the part affected. Heat also excites the capillary circulation, and cold diminishes it. In these and innumerable similar cases, the heart's action is not in the least affected.

The capillary circulation is that essential to nutrition, the presence of the heart being of little importance, except in large animals. The greater number of the inferior animals have no heart, but life cannot exist without a capillary or interstitial circulation.

*The cause of the systemic capillary circulation is the chemical affinity existing between arterial blood and the sides of the vessels or cells among which it flows.*—We have seen that the function of nutrition consists in the passage of oxygenized blood through the capillaries. This action demonstrates the existence of a considerable chemical affinity between this fluid and the vessels; in virtue of which it penetrates the basement tissue of the capillaries or moves along their axes. The advance of the arterial blood is a phenomenon analogous to that of the ascent of water in a glass tube; it arises from the attraction of the fluid and solid for each other.

This attraction explains the fact that the arteries are always found empty after death, whilst the veins are filled. So long as there is arterial blood, it is attracted by the sides of the capillaries, and hence the vessels which bring it are ultimately emptied.

The capillary vessel has arterial blood on one side, and venous blood on the other. The first contains an excess of oxygen, which is lost in the passage, being employed in effecting chemical changes in the capillaries. The question now arises, why is the current invariably in one direction from the arterial to the venous side? Because arterial blood has a greater affinity for the tissue than the venous blood; hence it not only advances in preference to it, but pushes the venous blood before it;—an effect analogous to the action of water on olive oil, in a capillary tube.

This capillary affinity not only is the cause of the circulation,

but it acts as a force, driving forward the volume of venous blood even to the right auricle, and by distending it, is the cause of the heart's action. In the *portal circulation* no other force can act, for the vessels of this system commence in the capillaries of the gastric, intestinal, mesenteric and other veins, and terminate in the portal capillaries of the liver. By the *vis à tergo* in the arterial capillaries, the large abdominal veins are filled, and by the drainage going on by the secretion of bile, a demand for fluid is supported—in the same way that the combustion of oil in a lamp creates a constant demand for more of the fuel.

The entrance of fluid from the intestines, and from various parts of the body into the absorbents, is also in virtue of a chemical affinity existing between the entering liquid and the alkaline fluid of these vessels.

The venous blood of the pulmonary arteries is driven by the contraction of the right ventricle of the heart, to the extremities of the vessels ramifying on the cells of the lungs. But the heart cannot drive it further. Exclude the oxygen of the air and it stagnates there, and venous congestion is the result. How does the venous congestion of asphyxia arise, if the heart has the power of driving the blood through the capillaries, or if that fabulous operation of contraction and dilation in the capillaries be the cause of its propulsion. Fabulous, for no one has seen it of the thousands of microscopical observers, and there is no muscular coat in these vessels. Asphyxia from venous congestion, as in drowning and the inhalation of ether, arises in a few minutes, long before life is extinct, without the nervous power being injured, and is relieved not by causing the heart to beat, and driving forward the blood, but by the establishment of artificial respiration, whereby it may be arterialized.

The function of respiration, by oxydizing venous blood, endows it with the power of advancing, by capillary affinity, into the trunks of the pulmonary veins, and filling the left auricle, which is thereby stimulated to contraction. Hence, by the action of the capillary force, the right and left auricles are filled, and by no power of suction, as is generally conceived.

Whatever lessens the supply of oxygen to the body diminishes, and whatever increases it, renders the circulation more rapid. The presence of oxygen in this fluid is therefore the remote cause of the circulation, for it is this agent which gives to arterial blood its affinity for the capillaries and tissues.

For the foregoing views, we are chiefly indebted to Professor Draper.

*Capillary action explains, besides the foregoing, many other operations occurring in the body.*—The penetration of liquids into the blood, the evacuation of serous and mucous fluids from

the tissues under the influence of irritants, are instances. If a strong solution of Epsom salts, nitre, or other saline bodies, be introduced into the stomach, they produce a diversion of fluid from the tissues by capillary action, in the same way that similar bodies placed in the endosmometer and plunged in water, solicit a current of fluid towards themselves. The purgative or emetic action of many bodies depends on this action.

Cold diminishes the capillary circulation, because it diminishes the chemical action between the oxydized blood and the tissues. Heat exercises the opposite effect. Stimulants and epispastics also act by increasing the capillary circulation locally.

Saline medicines cannot enter the blood, except when very dilute, because they attract fluid to themselves into the intestines, when concentrated.

Numerous medicines act by endowing the blood with a specific quality, which causes an increase or diminution of the affinity existing between it and the capillaries. On this subject, see the section on isomorphism, at page 158.

The relation of the capillaries to the circulating fluid, is also under the influence of the nervous system. For we find that instead of advancing, the blood sometimes becomes stagnant in the parenchymatous tissues, or on the contrary, it may be hurried forward with febrile rapidity.

The secretions are dependent on the affinity of certain fluids for the capillary tubes of the glands.

## URINE.

The urine in health is an amber-colored, limpid fluid, with acid reaction. Its sp. gr. is from 1.01 to 1.025, the difference being due to the variable proportion of water. It readily passes into the state of putrefaction, exhaling a urinous or ammoniacal odor. Chemical writers divide the secretion into three parts. 1. The *Urina potus*, which is produced shortly after drinking; 2. The *U. cibi* secreted after a meal; 3. The *U. sanguinis*, morning urine. Of these, the first contains an excess of fluid. The second is mixed with adventitious substances derived from the food, as coloring matters, essential oils, and an excess of saline bodies. The *urina sanguinis* is that to which the attention of the physician is to be turned, as affording a true indication of the state of the functions of the body.

The amount of urine voided in the day averages  $2\frac{1}{2}$  lbs., and contains about  $2\frac{1}{4}$  ounces of solid bodies, and rather less than half an ounce of nitrogen.



The normal composition of this important secretion is as follows:—

Water,	-	-	-	-	-	-	934.00
Solids,	-	-	-	-	-	-	66.00
<hr/>							
Of the solids there are, in 100 parts,							
Urea,	-	-	-	-	-	-	45.10
Uric acid,	-	-	-	-	-	-	1.50
Extractive matters with ammonia salts and chloride of sodium,						}	36.30
Alkaline sulphates	-	-	-	-	-	-	10.30
Alkaline phosphates	-	-	-	-	-	-	6.88
Phosphates of lime and magnesia	-	-	-	-	-	-	1.50

From this composition it would appear to be a secretion destined to remove from the body effete nitrogenized bodies and saline matters. It is rich in urea and ammoniacal bodies, which are highly nitrogenized, and contains some 16 per cent. of inorganic salts. The principal constituents are urea, ammoniacal salts and the phosphates, and some further observations are necessary concerning these bodies.

UREA is the characteristic compound of urine; it is the most highly azotized body known, containing 46.7 per cent. of nitrogen. Its formula is  $C_2H_4N_2O_2$ , or the same elements as cyanate of oxide of ammonium ( $NH_4O + CyO$ ).

It may be procured from concentrated urine, or artificially in the way pointed out at page 227. In the pure state, urea crystallizes in four-sided, transparent and colorless prisms, which dissolve in their own weight of water, and are still more soluble in hot alcohol. It has a cooling, saline taste, is inodorous, and permanent in the air. When heated, it melts, and at a higher temperature becomes decomposed into cyanate of oxide of ammonium, cyanuric acid, and ammonia.

It is neutral to test paper, but it unites with acids forming salts, of which the nitrate and oxalate are insoluble and characteristic; lime and the alkalis decompose it when assisted by heat, and there is formed a carbonate of the base; ammonia being evolved. By putrefaction, all the urea of urine disappears, being converted by union with water into carbonate of ammonia, which abounds in old urine, and gives it a pungent odor. This change is brought about by the action of the small amount of mucus voided with the urine, which, becoming oxydized by exposure to the air, acts as a ferment.

Urea in the larger animals, is the product of the changes occurring in the proteine matters of the body. The nature of this change has been stated to be similar to eremacausis. Carbon is rendered carbonic acid, hydrogen converted into water, and now we find that a portion of the nitrogen is changed into cyanic acid

( $C_2N_2O$ ) by oxydation ; another portion becoming ammonia, and uniting with the cyanic acid to form urea (*cyanate of oxide of ammonium*). This passes off by the kidneys chiefly, but a small portion appears to be exuded by the skin. It is generally believed that the urea exists ready formed in the blood, and is merely drained off. In Bright's disease, where there is granular disorganization of the kidney, urea accumulates in the blood to a great extent; this also occurs in cholera.

*The amount of urea depends upon the waste of nitrogenized matters, and the food.*—In violent inflammatory fevers its proportion rises in fluid urine, from 39 parts in 1000 to 47 parts, whereas it falls to 22 in asthenic diseases, chlorosis and dropsies. Dr. Percy has shown that it increases with exercise, for in these cases there is increased waste of the muscles; he observed an increase of upwards of one-fifth in the urine of a pedestrian undergoing the process of training. Lehmann and Simon concur in this result.

The quantity of urea rises in the urine from infancy to manhood and declines with age; it is also greater in men than women during the same periods of life.

Lehmann has instituted a series of experiments on himself, to determine the connection between the food, and the composition of the urine. The results of his researches are as follows; the numbers represent the actual amounts of the constituents of urine discharged in a day in grains:

<i>Urine.</i>	<i>Mixed diet.</i>	<i>Animal diet.</i>	<i>Vegetable diet.</i>	<i>Diet of starch, sugar and oil.</i>
Solid constituents	1044.5	1347.0	912.3	641.8
Urea	499.5	819.3	346.1	237.3
Uric acid	18.0	22.8	15.7	8.0
Extractive and organic matters	203.4	113.5	295.3	272.1

The urine of the herbivora readily becomes alkaline, and contains less urea than that of man and the carnivora, and is also charged with hippuric and other organic acids. But it is a very interesting fact, as discovered by Barreswil and Bernard, that the urine of starving herbivorous animals becomes identical with that of the carnivora; abounding in urea, evidently produced from the metamorphoses of their azotized tissues. On the other hand, Scherer has found that a girl living on apples exclusively, voided urine which abounded in hippuric acid, and was turbid and otherwise similar to that of herbivorous animals.

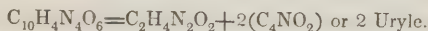
URIC ACID is found only in small quantities in the urine of man and the carnivora; it is absent from that of the herbivora, but abounds in the urine of serpents and birds. It becomes less in man under the influence of exercise and vegetable food, and increases in sthenic inflammations and in persons of slothful

habits—hence, its appearance in excess in the urine of those suffering from gout. The normal appears to be about 1.1 in a thousand parts of urine, but it may be increased to 5 or 6 parts.

Uric or lithic acid is a glistening white powder, tasteless, inodorous, and almost insoluble in cold water, and but slightly soluble in the boiling fluid. Under the microscope, it appears as minute crystalline scales. It is a constituent of the red sediment of the urine, being stained by a red coloring matter (*uro-erythrine*); of many urinary calculi being either pure or combined with ammonia as urate of ammonia; and of gouty concretions, which contain urate of soda.

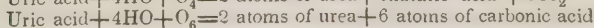
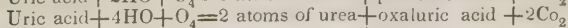
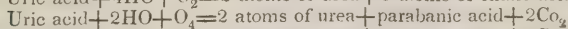
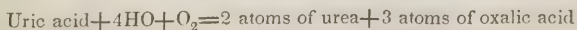
It is insoluble in ether and alcohol, but dissolves in dilute nitric acid with the evolution of carbonic acid and nitrogen. This solution, when evaporated, acquires a pink color, which, on the addition of ammonia in excess, changes to a purple-red (*murexide*, *purpurate of ammonia*). These changes are characteristic of uric acid.

The formula for uric acid is  $C_{10}H_4N_4O_6$ ; but these elements do not appear to be united together with the same force, for the compound is readily split up into a variety of products by oxydation, among which urea is often produced. Hence, Liebig regards it as a compound of urea with a compound radical called Uryle (*Ur*) or cyan-oxalic acid. Or



When uric acid is boiled with water and the peroxide of lead, it is resolved into one atom of urea, an atom of allantoin and 2 atoms of hydrated oxalate of lead. In this case, the urea of the above formula is set free, and the two atoms of uryle combining with water and oxygen derived from the lead, become divided into allantoin and oxalic acid. The *allantoin* or *allantoic acid* thus produced, is identical with the principal ingredient of the allantoic fluid of the calf. It may be obtained in fine rhomboidal crystals from this excretion, and consists of  $C_4H_3N_2O_3$ . Allantoin is converted by heat, and the alkalies or acids into oxalate of ammonia. Hence we perceive a relation between uric acid, urea, and oxalic acid, which last is a product of diseased urine.

Other interesting bodies are obtained by the oxydation of uric acid, the principal of which are alloxan, parabanic, oxaluric and oxalic acids. The following scheme shows the order of these changes and how uric acid passes into urea by the addition of oxygen and water:



Hence, by the addition of water and oxygen, to uric acid, in the functions of the body, oxalic acid may be generated, and it may lay the basis for the mulberry calculus—again, as we have already stated, by vigorous exercise the uric acid of urine diminishes, being converted into urea and carbonic acid by the action of inspired oxygen. The active beasts of prey void urea only, the inactive tortoise and serpent uric acid alone.

These changes are interesting in investigating the origin of stone in the bladder, for, as will be understood, whatever diminishes the supply of oxygen to the blood, as slothfulness or chronic inflammation—in which changes occur too rapidly in a part, and out of proportion to the supply of oxygen—will generate uric acid in the place of urea. On the other hand, excessive exercise, with a deficiency of food, will lead to the production of oxalic acid calculus, especially in those parts of the country where water impregnated with lime, is ordinarily used.

*Hippuric Acid* is, by Liebig, regarded a normal constituent of human urine, but this is not certain. The quantity is, moreover, small, but in the urine of the herbivora, it is abundant in combination with potash. It is produced in man, by the ingestion of benzoic acid, to which it is allied, and is said to appear when a vegetable diet is persisted in.

It occurs in long transparent, four-sided crystals, without odor, and of a faint bitter taste. It is freely soluble in alcohol, less so in ether, and but to a small extent in water. It forms soluble, crystallizable salts, with the alkalies and alkaline earths.

It melts into a colorless, oily body, at a moderate heat, but at a higher temperature is decomposed and resolved into benzoic acid, benzoate of ammonia, and a small quantity of an oily body, having the peculiar odor of the Tonquin bean.

*The Saline Matters of the Urine.*—In healthy urine, two, or according to some authors, three classes of salts exist—the sulphates, phosphates and lactates; there is also common salt, (*chloride of sodium*,) in variable proportions. The sulphates are alkaline and soluble, they are derived from metamorphoses going on in the body, for some of the proteine matters contain sulphur; and also directly from the food. Dr. Percy witnessed an increase in the amount of sulphates during active exercise.

The phosphates are highly interesting. There are phosphates of ammonia, potash, soda, lime and magnesia belonging to the urine. These are all tribasic, and some are double salts. The acid reaction of urine depends upon the presence of acid tribasic phosphate of soda, and the phosphate of lime and magnesia therein, are dissolved by this salt in the fresh secretion. But in those dyspeptic and asthenic diseases, in which the urine is alkaline, these



bodies are precipitated, and the fluid is voided in a turbid state, or produces a deposit shortly after its separation from the body.

Some remarks will be found on the composition of the phosphates of the urine, at page 205, which renders it unnecessary for us to enter further into the subject.

The phosphates are mainly produced by the metamorphosis of the tissues, but some enter the body with the food. The phosphates of soda and ammonia are peculiarly interesting, as derived from changes transpiring in the muscular and nervous systems. Increased action in the brain and nervous system, produced by excessive application or disease, is attended with an increase of the phosphates of soda and ammonia, and frequently with an abundant deposit of phosphate of lime and magnesia, which are no longer suspended in the urine by the phosphate of soda, in consequence of its loss of acid reaction.

**FOREIGN BODIES IN THE URINE.**—As this secretion contains the effete matters of the blood, it is subject to considerable alterations. When the function of the liver is impeded, the coloring matter of the bile or biliphæin, is separated by the kidneys. So when the mammary glands are first excited in pregnancy, and a small amount of milk formed, it re-enters the blood, and is discharged by the kidneys, constituting the substance called *kiestien*.

*Kiestien* consists of caseous matter; it usually makes its appearance in the urine of pregnant females about the fourth month. It appears as bullæ, like the small masses of fat floating on cold mutton broth, from the second to the fifth day after the urine has been voided. Dr. Zimmermann states that it contains vibrios. It is a good test of pregnancy, but may be present whenever there is a vicarious discharge of milk by the urine, owing to any cause.

In diabetes, a large quantity of glucose is found in the urine, which may be tested by Trommer's test (page 243) or by fermentation.

In organic diseases of the kidneys, albumen is often a constituent of the urine. It is recognized by the action of heat and nitric acid, which coagulate the albumen. The precipitate of nitrate of urea formed in urine, which is highly concentrated, is not to be mistaken for coagulated albumen; it differs in color and crystalline appearance.

Substances, taken as food and medicines, also change the constitution of the secretion. Several essential oils impart to it a peculiar odor, whilst coloring matters, as rhubarb, madder and other bodies, stain it. The vegetable acids appear in the urine, as carbonates of soda and other bases, having become changed in the circulation into the carbonic acid, and entering in combination with

bases found in the stomach and food. The alkaline organic salts, as the tartrate of soda, citrate of potash, &c., also appear in the urine as carbonates of their respective bases. These substances may be taken up to such an extent from food, or as medicines, as to give the urine an alkaline reaction.

The alkaline salts with mineral acids, as the sulphate of potash, carbonate of soda, phosphate of soda, &c., appear in the urine without change. The haloid alkaline salts, as the chloride of sodium, ferrocyanide of potassium, iodide of potassium, also appear unchanged in the urine. It is to be remarked, however, that these bodies do not enter the absorbents from the stomach and bowels, except in minute quantities, and if strong solutions of them be administered, they may be voided in the feces, or may produce vomiting or purgation.

Besides adventitious saline matters, coloring matters, essential oils and other mineral bodies, the urine may contain abnormal bodies, as a blue coloring matter (*cyanourine*), resembling indigo, fatty bodies, or it may furnish torulæ, and other organized structures. Instead of being acid and limpid, it may be strongly alkaline, turbid, and may even exhale a putrid odor in consequence of the presence of carbonate of ammonia.

**THE SEDIMENTS AND CONCRETIONS OF THE URINE.**—Calculi consist, for the most part, of the same substances as the sediments so common in urine. They are made up of several kinds of materials, and nucleated about some foreign substance, as a little blood, pus or other body. The principal varieties are:

*The Uric (or Lithic) Acid Calculus.*—The calculus is hard, of a light-yellow brown tint, smooth or warty in appearance, distinctly concentric, and somewhat crystalline. It burns away before the blowpipe, exhaling an ammoniacal odor, is soluble in solution of potash with heat, and yields murexide when warmed with nitric acid, and mixed with a little ammonia.

Uric acid forms the principal portion of the brick red or lateritious sediment of the urine in fevers; it may be distinguished by its crystalline appearance under the microscope, and by being insoluble when the urine is heated or treated with acetic acid or ammonia. The coloring matter is termed purpurine or uroerythrine, and is present in very minute quantity. In these cases the steady use of alkaline remedies has served occasionally to dissolve the calculus and remove the gravel.

*Urate of ammonia* forms small calculi, and is common as a sediment. The calculus is made up of concentric layers, and is usually mixed with uric acid; it is smooth or slightly tuberculated; the fracture is fine and earthy. It decrepitates before the blowpipe, evolves ammonia when heated in a solution of potash, and

is soluble in solutions of the alkaline carbonates, whilst uric acid is not so.

The sediment of urate of ammonia is usually of a light fawn color, amorphous, and dissolved by heating the urine; in the latter respect it differs from the phosphatic deposits, which are not dissolved by heat.

*Phosphate of Lime Calculus.*—It is uncommon; it forms a pale brown, smooth calculus, of separable laminæ. The calculi of the prostate gland are of this kind. It is common as a sediment, and is recognized by being insoluble in hot urine and ammonia, but readily soluble in acetic acid.

*Phosphate of Ammonia and Magnesia—Ammoniaco-Magnesian Phosphate—Triple Phosphate.*—This calculus is white, and the surface often presents minute crystals; its texture is hard, somewhat compact and translucent. Heated before the blowpipe, it exhales ammonia, and leaves a white residue. It is readily dissolved by acids.

*The phosphate of lime with phosphate of magnesia and ammonia—The fusible calculus.*—This is a compound of the preceding two, is very common, and often attains a large size. It is whitish, smooth, earthy and soft. Before the blowpipe it fuses into a bead. It is also readily soluble in acids.

*Oxalate of Lime calculus—Mulberry calculus.*—This is of a brown color, rough and warty, resembling a mulberry. It is very hard and imperfectly crystalline. Before the blowpipe this calculus burns into a white voluminous ash of carbonate of lime. It is easily soluble in nitric acid.

Sediments of oxalate of lime are not uncommon; they present minute transparent octahedral crystals under the microscope, are not soluble in ammonia, acetic acid, nor by heat. Their presence indicates a tendency to the formation of urate of ammonia.

*Cystic Oxide—Cystin.*—This is an abnormal body found very rarely in the form of calculus or as a sediment. Its composition is  $C_6H_6NO_4S_2$ ; hence it contains 25.5 per cent. of sulphur. It is neither acid nor alkaline, is combustible, and exhales a peculiar odor. It dissolves both in acids and alkalies. The calculus is distinctly crystalline, and presents a waxy appearance externally.

The sediment is found under the microscope to consist of six-sided plates, and it is distinguished from other sediments by its solubility in ammonia.

*Xanthic Oxide—Uric Oxide—Urous Acid.*—This is also a peculiar and rare body not present in normal urine. The calculus has a brown surface, scaly fracture, is brown interiorly, and acquires a resinous appearance when rubbed. It is soluble in alkalies, but precipitated from them by carbonic acid. The composition of xanthic oxide is  $C_{10}H_4N_4O_4$ , and it differs from uric

acid in containing two atoms less of oxygen. It also differs from uric acid in being insoluble in the alkaline carbonates.

Besides the preceding bodies, carbonate of lime, siliceous matters, and fatty matters, have been found in calculi. Several of the preceding bodies are often stratified together.

#### THE NERVOUS MATTER.

The brain and nervous matter consist of a mixture of albumen and peculiar fats. One hundred parts contain about 20 of solids, of which, according to Frémy, one-third is albumen, one-third fatty matters, and the rest saline and extractive bodies. The fats are cholesterine, common fats, and two which are peculiar—the *cerebric acid* and *oleophosphoric acid*.

*Cerebric acid* is a white, crystalline and granular solid; it is slightly soluble in water, to which it imparts a gelatinous appearance. It is a true fat acid, and forms compounds which are for the most part insoluble. It is distinguished from other bodies of this class by containing both nitrogen and phosphorus, and is the peculiar component of the brain and nervous system.

Its composition per cent., according to Frémy, is as follows:

Carbon	-	-	-	66.7
Hydrogen	-	-	-	10.6
Nitrogen	-	-	-	2.3
Oxygen	-	-	-	19.5
Phosphorus	-	-	-	0.9

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100.

The amount of cerebric acid is much greater in the vesicular portion of the brain than in the nerves or in the fibrous portion. L'Héritier has also determined that the amount of phosphorus, or, what is the same thing, cerebric acid, increases from infancy to manhood, and declines with old age, and that idiots have the least amount. In infancy the amount is about 0.8 per cent. of the brain; between 15 and 18 it increases to 1.6; in manhood it rises to 1.8 and 2, and in old age falls to 1.0 per cent. In idiots, it seldom exceeds 0.85 per cent.

By combustion and the changes of oxydation in the brain, the phosphorus of cerebric acid is converted into phosphoric acid.

*Oleophosphoric acid* is apparently a derivative of the preceding, and it has been resolved into phosphoric acid, and a body nearly resembling olein, and termed *cerebroleine*. It is in the combined state a soft oily body, soluble in alcohol and ether. It disappears very rapidly from the brain, and is hence regarded as a product of the metamorphosis of its constituents, and especially of cerebric acid.



There is a singular connection between the activity of the nervous centres, whether in health or as a result of disease, and the proportion of phosphates, especially of soda and ammonia, in the urine. In insanity, myelitis, and great excitement of the brain, the urine is either turbid, or soon precipitates phosphates. It is often alkaline from the presence of the alkaline tribasic phosphate of soda, and soon becomes ammoniacal after emission, forming the phosphate of magnesia and ammonia.

## BONES, HORN, ETC.

Bones consist of phosphate of lime, a small amount of carbonate of lime and phosphate of magnesia, and animal matter, principally glutine. The following are the proportions, according to Berzelius, in a specimen of human bone:

Glutine	-	-	-	-	-	32.17
Vascular substance	-	-	-	-	-	1.13
Phosphate of lime with a little fluoride of calcium					}	53.04
Carbonate of lime	-	-	-	-		11.30
Phosphate of magnesia	-	-	-	-		1.16
Soda and common salt	-	-	-	-		1.20
						<hr/> 100.00

But the bones of the aged contain more mineral matter than those of the young, and the hard bones, especially the enamel of the teeth, than the spongy bones.

*Horn, hair and feathers* are insoluble bodies, consisting of gelatine, with different amounts of saline matters; but their constitution is little known. Caustic potash with heat dissolves them all, with the evolution of ammonia, and acids throw down a substance resembling proteine.

## PART V.

### THE METALS.

THE metals are those elementary bodies, which are usually electro-positive in their reaction, have a peculiar brilliancy, called the metallic lustre, and are good conductors of heat and electricity. There are from 42 to 45 of these bodies, which are enumerated in the table of equivalents at page 135.

They have usually the solid form, and a considerable specific gravity; but potassium, sodium and other metals, are lighter than water, whilst mercury is fluid.

Some possess malleability, as iron, copper, gold, silver, whilst others, as antimony and arsenic, are extremely brittle.

Most of them possess considerable fixedness in the fire, and a high fusing point, but zinc, arsenic, cadmium, mercury, potassium, sodium and tellurium, are readily distilled.

The metals readily unite with oxygen and the haloid bodies, and also with each other. The latter compounds are termed amalgams when mercury is present, and alloys, when this metal is absent.

Few metals are found in the native or elementary state in nature, but usually as oxides, sulphurets, arseniurets, carbonates, or in other states of combination. These are called ores, and the processes of metallurgy are chiefly intended to separate the metal from its compounds.

Their affinity for oxygen differs widely, and as this is an important feature in the chemical history of the metals, it is customary to group them, according to their action towards this body.

There are three groups: 1st. Metals which decompose water, to combine with its oxygen at common temperatures, and are therefore scarcely known in the elementary state; 2d. Metals which decompose water at a red heat; 3d. Metals which cannot decompose water at all, and have, therefore, but an inferior degree of activity.

*1st Group.*

Potassium,  
Sodium,  
Lithium,  
Barium,  
Strontium,  
Calcium,  
Magnesium.

*2d Group.*

Aluminum,  
Glucinum,  
Thorium,  
Yttrium,  
Zirconium,  
Lanthanum,  
Cerium,  
Manganese,  
Iron,  
Nickel,  
Cobalt,  
Zinc,  
Cadmium,  
Tin.

*3d Group.*

Chromium,  
Vanadium,  
Tungsten,  
Molybdenum,  
Osmium,  
Columbium,  
Titanium,  
Uranium,  
Copper,  
Lead,  
Bismuth,  
Mercury,  
Silver,  
Gold,  
Palladium,  
Platinum,  
Rhodium,  
Iridium.

Another division is common, but less perfect, into: 1st. *Alkaline metals*, which includes potassium, sodium and lithium—2d. *Alkaline earths*, barium, strontium, calcium and magnesium—3d. The true earthy metals, including the five first bodies of the above second group—4th. Imperfect metals; and 5th, the noble metals, which are but little acted on by reagents, and form the last seven bodies of the above third group.

In the following pages it is our purpose only to direct the attention of the student to the chief metallic bodies, and not to enter into their chemical history, which is of little importance to the medical man. Nor do we propose to detail all the metallic salts of medicinal value, for these are treated of at length in the works on *Materia Medica*.

## POTASSIUM.

Potassium, and the metals of the first group, are only obtained in the elementary state by complicated processes, in consequence of their intense affinity for oxygen.

It is a bluish-white metal, of a silver-like lustre, brittle at 32° F., but soft at ordinary temperature. It melts at 150 F., and boils at a red heat, yielding a greenish vapor. Its equivalent is

39.26 and symbol K. Its sp. gr. is .865, hence it floats on water; but it decomposes this fluid, and burns with a beautiful pink flame. It is a body of interest in the laboratory as a deoxydizing agent, but of no importance in medicine or the arts.

It forms two oxides; KO, the protoxide, which is the basis of caustic potash; and  $\text{KO}_2$ , the peroxide, which is scarcely known. It also combines with great facility with sulphur, chlorine, phosphorus and the haloid bodies generally, forming substances which are often of considerable interest in the arts and medicine. Some of these have been noticed in the articles on the haloid bodies.

*The hydrated oxide of Potassium—Caustic Potash; KO+HO.*—Although potassium combines with oxygen so readily, the oxide is scarcely known, for if water be present, it instantly unites with it and forms the hydrated oxide or caustic potash.

Caustic potash is a white, slightly translucent solid, having an intense affinity for water, and disorganizing animal tissues to combine with it. It has a soapy feel and is eminently alkaline. It neutralizes the acids, discolors turmeric, and restores the color of reddened litmus. It unites with the carbonic acid of the atmosphere, becoming carbonate of potash if left exposed. The source of this body is the ashes of plants, which derive it from the soil.

Nearly all its salts are soluble in water, but an excess of tartaric acid precipitates it as cream of tartar, or the bitartrate of potash. The bichloride of platinum, and perchloric acid also precipitate it from its compounds, when they are in the concentrated state.

Caustic potash is used as an escharotic, and in dilute solution as an antacid, and in irritable states of the gastro-enteric membrane. In the laboratory it is employed as a powerful solvent and catalytic agent, especially towards organic bodies.

*The salts of oxide of potassium; The salts of potash.*—*The carbonate of potash* is the principal constituent of commercial pearlsh; it has a disagreeable alkaline taste, a soapy feel, and is deliquescent. There is a second carbonate, called the bicarbonate, formed by passing a stream of carbonic acid through a solution of the above. *The sulphate of potash* is anhydrous, saline, and crystallizes in four-sided prisms. There is also an acid sulphate called the bisulphate of potash.

*Nitrate of potash*, or common nitre, is obtained in an impure state, as an exudation on the surface of the earth in India and elsewhere. When pure, it forms anhydrous six-sided prisms, which have a cooling saline taste. It is extensively employed as a refrigerant and diuretic in medicine; and in the arts, for the manufacture of gunpowder, nitric and sulphuric acids.

The bitartrate of potash, or cream of tartar, and the citrate and tartrate are employed as refrigerants, and in large doses are laxative.



## SODIUM.

Sodium nearly resembles potassium, but is of a brighter color, and does not inflame spontaneously on water. If the water be heated, it burns with a rich yellow flame, which is characteristic of this body and its compounds. Its symbol is Na, and equivalent 23.3.

Sodium unites with oxygen with great avidity. It forms three compounds, of which NaO, or oxide of sodium or soda, is the most important. But like potash, this is scarcely known, except in the hydrated state.

*Hydrated Oxide of Sodium—Caustic Soda; NaO + HO.*—This resembles potash, but is milder. It is deliquescent, and absorbs carbonic acid from the air, becoming converted into the carbonate of soda. Soda is derived from sea weeds, and by the decomposition of common salt.

The salts of soda may be formed by bringing the acids, &c., in contact with this body, or with the carbonate. They are all soluble, and usually much milder than the corresponding compounds of potash.

*Chloride of Sodium*, or common salt (NaCl), is one of the most important saline bodies. It belongs to the class termed haloid salts, being a compound of two elements, and not of an acid and oxydized base. To the same class belong the iodides, bromides, cyanides, &c.

It abounds in the sea and saline springs, and is also found in mines, as rock salt. When pure, it crystallizes in translucent cubes, is without water of crystallization, and fuses at a red heat. Its taste is well known. It is not more soluble in hot than cold water, this menstruum dissolving about 33 per cent. of the salt. Its antiseptic properties make it an essential body to the human family; it is also used as food, and in chemical manufactures. Salt is a speedy emetic, acting in doses of half an ounce, and as a laxative in the dose of a drachm, dissolved in a small quantity of water.

*Salts of Oxide of Sodium; Salts of Soda.—Carbonate of Soda* is obtained from the ashes of sea weeds, and by the decomposition of common salt. It is extensively used as the basis of soaps. In the pure state it forms rhombic octahedrons, effloresces in the air, is very soluble, and has an alkaline taste. The bicarbonate, which is used in medicine, is made by transmitting a current of carbonic acid through the solution of the preceding.

*Sulphate of Soda*, or Glauber's salts, forms prismatic crystals;

it effloresces in the air, is bitter and purgative. *Nitrate of Soda* nearly resembles nitre, but is rather deliquescent.

#### LITHIUM.

Lithium is a rare metal, resembling both in the elementary state, and in its compounds, sodium. Its compounds yield a red flame, when heated before the blowpipe, and its carbonate is only sparingly soluble. Its symbol is L, and equivalent 6.4.

#### BARIUM.

Barium is a metal resembling cast iron in appearance, but not permanent in the air. Its symbol is Ba, and equivalent 68.7. It belongs, along with calcium, strontium, and magnesium, to the alkaline earths, which neutralize bases, and discharge the colors of vegetables, but differ from the alkalies, in the sparing solubility of their oxides and salts.

The protoxide ( $\text{BaO}$ ) forms a hydrate, which is termed barytes; it is acrid and somewhat caustic. The salts are not used in the arts. The sulphate is a common mineral, called heavy spar, and is employed to adulterate white lead. The soluble salts of barytes are irritant poisons; their antidote is sulphate of soda. The nitrate yields, when burnt, a green flame.

#### STRONTIUM.

Strontium is closely allied with barium. Its symbol is Sr, and equivalent 43.8. The sulphate is not so insoluble as the sulphate of barytes, and its nitrate yields, when burnt with charcoal, a rich red flame.

#### CALCIUM.

Calcium is scarcely known as a metal. Its symbol is Ca, and equivalent 20.5. It is the basis of lime, which is the protoxide.

*The Protoxide of Calcium* ( $\text{CaO}$ ), or lime, is obtained in large quantities, by burning marble, chalk, and limestone, which are carbonates of lime. The shells of oysters, lobsters, and shell fish, also yield it when burnt.

When recent, it is termed quick or caustic lime, and is very active, but by exposure to the air or the action of moisture, it becomes milder, and changes more or less completely into slaked or hydrated lime. Lime is slightly soluble, and the solu-

tion, termed lime-water, has an alkaline taste, and is a good test, and antacid medicine. By exposure to the air, lime absorbs carbonic acid, whether solid or in solution, and becomes resolved into carbonate of lime, losing its caustic properties.

Solutions of lime, or its salts, are readily known by the action of oxalic acid, or oxalate of ammonia, which throws down the white insoluble oxalate of lime.

*The Chloride of Calcium*, is a very deliquescent body, and employed in the laboratory for the purpose of drying gases, and in organic analysis. The *fluoride* is the beautiful mineral, called Derbyshire or fluor spa.

*Salts of the Protoxide of Calcium; Salts of Lime.*—The *carbonate* is an abundant mineral, being the sole or principal ingredient in the varieties of marble, limestone, and chalk. It is insoluble in pure water, but is slowly dissolved by that which contains carbonic acid. The carbonate yields its carbonic acid, when acted on by most acids, and also by heat. When chalk is prepared by washing, it forms the *creta preparata* of pharmacy, and is a good antacid.

*The Sulphate of Lime*, gypsum, or plaster of Paris, is a common mineral. It occurs in clear crystals, usually in tables derived from the rhombic prism, and also as a white massive body. It is sparingly soluble in water. When calcined it loses water, and becomes plaster of Paris, acquiring the property of setting into a solid with water, and is hence used to obtain casts. It is much employed in agriculture, as a source of sulphates to plants.

*Phosphate of Lime* exists in bones, in the urine, and other animal substances, as well as in the seeds of plants. This is a tribasic phosphate. It is soluble in the acids, but not in water.

*Bleaching Powder*, usually called chloride of lime, is made by bringing hydrate of lime in contact with chlorine. It is a white powder, having a slight odor of the gas, and exhaling it freely when moistened with an acid solution. It is a valuable disinfecting agent.

## MAGNESIUM.

MAGNESIUM is a white, malleable metal, which melts at a red heat, and readily oxydizes, forming the protoxide or magnesia. Its symbol is Mg, and equivalent 12.7.

*Protoxide of Magnesia—Calcined Magnesia; MgO.*—It is a white, light powder, and sparingly soluble. It is procured by heating the common carbonate to redness.

It is slightly alkaline in its reaction, and neutralizes the acids

perfectly, forming an extensive class of salts, most of which are soluble.

It is distinguished by the solubility of its sulphate, and in blow-pipe analysis, by imparting to a small quantity of the chloride of cobalt a pink tint.

*Salts of the Protoxide; Salts of Magnesia.*—The carbonate is a common mineral; it forms a very light, sparingly soluble, white powder. It dissolves freely in a solution of carbonic acid, and may be used in this form in medicine. All the salts of magnesia may be obtained by saturating this body. It is much used in medicine, as an antacid and laxative.

*The Sulphate of Magnesia* is common Epsom salts. It is obtained by neutralizing the native carbonate by sulphuric acid. It crystallizes in four-sided prisms, which have a disagreeable bitter-sweet taste, and dissolve in about their weight of water. *The phosphate of magnesia and ammonia* is found in decaying urine, and forms a variety of calculus.

#### ALUMINUM.

Aluminum has been procured, in small quantity, as a gray powder, which melts below a red heat, and takes fire in the air, burning into the sesquioxide or alumina. Its symbol is Al, and equivalent 13.7.

Alumina, or the sesquioxide ( $\text{Al}_2\text{O}_3$ ), is the basis of clay, and the principal constituent in granite, slate, and the varieties of earthenware. In the pure state, it is a white, insoluble body, which neutralizes acids.

Its principal salts are alum, which is a sulphate of alumina and potash, and the acetate, which is employed in dyeing as a mordant.

GLUCINUM, THORIUM, YTTRIUM, ZIRCONIUM, LANTHANUM and CERIUM are bodies scarcely known; they are found only in a few rare minerals, and have not been employed in the arts or medicine.

#### MANGANESE.

This is a white metal, obtained with some difficulty from its ores, and rapidly oxydizing in the air. Its sp. gr. is 8.013, and it is very infusible. Its symbol is Mn, and equivalent 27.7.

It forms seven oxides, of which the protoxide ( $\text{MnO}$ ), is of a green color and basic, forming numerous salts—the peroxide ( $\text{MnO}_2$ ) is a common black mineral, called in commerce, black oxide of manganese; it is much used in the arts, as a source of oxygen and in the preparation of chlorine. When heated, the



peroxide loses oxygen, and becomes converted in the sesquioxide ( $\text{Mn}_2\text{O}_3$ ), which is basic, and isomorphous with the sesquioxide of iron. Two of its oxides, manganic ( $\text{Mn}_2\text{O}_5$ ), and permanganic acid ( $\text{Mn}_2\text{O}_7$ ), have the properties of acids, and unite with the alkalis and other bases. The manganate of potash is termed the mineral chameleon, from the changes in color which its solution undergoes when exposed to the air. It is first green, then purple, blue, and finally red.

The salts of the protoxide of manganese have a reddish color usually; they are little known. The protosulphate is used in dyeing, for the production of a brown color.

## IRON.

Iron is found in meteoric stones, and to a small extent, native; but more commonly in the state of oxide, carbonate, and sulphuret.

The most abundant ore is termed the clay iron ore; this is reduced, by carbonaceous matter and lime, in a smelting furnace. The first product of the reduction is impure or cast iron, which contains silicious and other impurities, and from three to five per cent. of carbon. It is brittle, and much harder than pure or soft iron.

Soft or malleable iron is obtained from the preceding by exposing it in the melted state for some time to the action of the air of the flue in a reverberatory furnace; by this means the carbon is burnt out. The metal changes in color, loses its crystalline appearance, and becomes exceedingly malleable, ductile and tough. Its sp. gr. is 7.7, and may be slightly increased by hammering. Its symbol is Fe (from ferrum) and equivalent 27.18.

Pure iron is obtained as a fine dark powder by passing a stream of hydrogen gas through a solution of the proto-salts. In this state it can be inflamed when dry, by a red heat, and burns with brilliant scintillations. This form has been introduced as a medicine, and is exhibited in pills made up with syrup as a mild chalybeate. It is preferable to the old preparation of iron scales from the forge.

Steel is made by heating alternate strata of charcoal and plates of iron, or by causing carburetted hydrogen to act on the fused metal. It possesses remarkable elasticity, when cooled suddenly, is more fusible than soft iron, and brittle. It contains about 1.5 per cent. of carbon.

*Oxides.*—Iron soon rusts in moist air, and is otherwise subject to oxydation. There are four oxides, the *protoxide* ( $\text{FeO}$ ), which is basic and exists in numerous salts of iron—the *black oxide*,

( $\text{Fe}_3\text{O}_4$ ), which is magnetic, and forms the natural loadstone; it is supposed to be a mixture of the protoxide and peroxide; this is also found in the scales of the Smith's forge, and has been used as a chalybeate. The *sesquioxide* or *peroxide* ( $\text{Fe}_2\text{O}_3$ ), which abounds in rust, and may be precipitated from the persalts of iron as a brown magma by the action of the alkalis; this is the hydrated peroxide used as an antidote to arsenious acid. Lastly, *ferric acid* ( $\text{FeO}_3$ ), which is obtained in combination with potash by heating the sesquioxide with nitrate of potash, by which there is formed ferrate of potash; this is instable, and the acid has not been separated.

There are also chlorides, iodides, bromides and sulphurets of iron. The *protochloride* ( $\text{FeCl}$ ) is an exceedingly soluble greenish-yellow crystalline and deliquescent body, of a styptic taste, and used in medicine as a chalybeate under the name of muriate of iron. The *protiodide of iron* ( $\text{FeI}$ ) is an esteemed preparation in scrofulous diseases; it is readily made by digesting together iron wire in tincture of iodine. It is a pale green crystalline body, but very deliquescent and soluble, and becoming changed by exposure in the air to the periodide, which is of a brown color.

The *protosulphuret of iron* ( $\text{FeS}$ ) is a brown brittle solid, made by heating together scraps of iron and sulphur. It is insoluble and used in the preparation of sulphuretted hydrogen. The bisulphuret is an abundant mineral product called iron pyrites. It crystallizes in octahedrons and figures derived from it, and has a rich metallic color like brass. Prussian blue is a ferrocyanide of peroxide of iron.

*The salts of the oxides of iron.*—The *protosulphate of iron* is the green vitriol or copperas of commerce. It crystallizes in oblique prisms of a green color, which effloresce and become changed into the persulphate by exposure to air and moisture. It is a styptic and emetic body, and is but little used in medicine. In the arts and in dyeing, it is extensively employed.

The *protocarbonate of iron* is a whitish insoluble body procured by the action of potash or soda on a solution of the protosulphate. It is a useful chalybeate, but readily changes when exposed to moisture and air. This body is present in ferruginous springs, being suspended by carbonic acid in a solution of which it is soluble. It also abounds in the clay iron ores.

The principal persalts are the nitrate, peracetate and persulphate. These are used in dyeing.

Solutions of the protosalts of iron yield a white precipitate with the ferrocyanide of potassium (yellow prussiate of potash), which becomes blue by exposure to the air; in the persalts, this precipitate is blue (Prussian blue) at first. Infusion of galls, and other forms of tannic acid, strike a blue-black color, which is the

basis of common writing ink. The protosalts in solution or in damp air absorb oxygen, and become converted into persalts, hence there is much difficulty in preserving them; in pharmacy, this is partially accomplished by the aid of sugar.

#### NICKEL.

Nickel is a white malleable metal, requiring a high heat for fusion. It is magnetic, and has a sp. gr. of 8.5. It is little used except as a constituent of German silver. Its symbol is Ni, and equivalent 29.6. Its salts have a characteristic green color.

#### COBALT.

Cobalt is a white brittle metal, very infusible, and sp. gr. 8.5. Its symbol is Co, and equivalent 29.5. The pure metal is not used, but its oxide is of value as a blue coloring material for glass and earthenware goods.

The chloride yields a pink solution, which may be used as a sympathetic ink; when written on a pinkish paper, it is invisible, but turns of a rich green color as often as it is warmed before the fire.

#### ZINC.

Zinc abounds in nature as a sulphuret (zinc blende) and silicate. The metal is of a bluish gray; it melts below redness, and burns at a red heat into the white oxide. It distills over in a closed vessel at a high temperature. Its specific gravity is 7.00. It is crystalline and brittle at ordinary temperatures, but becomes malleable, and can be rolled at 300° F. It is much used as an alloy with copper and other metals, and in the metallic state for roofs. Its symbol is Zn, and equivalent 32.3.

The oxide (ZnO) is a white insoluble powder; it is basic, and forms colorless salts, of which the *sulphate of zinc*, white vitriol, is the principal. This crystallizes in colorless prisms with six equivalents of water of crystallization; it is very soluble, has a severe styptic taste, and reddens litmus paper. It is one of the most active emetics known in doses of gr. x to gr. xv.

The chloride of zinc is a butyraceous solid; it is used in soldering.

#### CADMIUM.

Cadmium resembles tin, but is nearly as volatile as mercury. It is not put to any use; its symbol is Cd, and equivalent 55.8.

## TIN.

It is found in nature somewhat sparingly as an oxide. The metal is white like silver, but less lustrous, and softer. It oxydizes superficially only. Its sp. gr. is 7.2; it melts at about 400, and burns in the open air at a high temperature into an oxide. Its symbol is Sn (from Stannum), and equivalent 58.9.

It is used to protect iron from oxydation in the common tin plate, and as an alloy in solders and pewter.

There are three oxides of tin: the *protoxide* ( $\text{SnO}$ ), which is a black powder and combustible, changing into the peroxide; its salts reduce the noble metals, and yields with the chloride of gold a rich blue color called the purple of Cassius;—the *sesquioxide* ( $\text{Sn}_2\text{O}_3$ ) is scarcely known;—the *peroxide* ( $\text{SnO}_2$ ) has feeble acid properties, and has been termed stannic acid; it is a white powder; fused with glass, it forms common white enamel.

There are two chlorides: the *protochloride* ( $\text{SnCl}$ ), a gray resinous-looking body used as a deoxydizing agent—the *bichloride* ( $\text{SnCl}_2$ ), formerly called the *fuming liquor of Libavius*. It is a thin colorless fluid, yields a colorless vapor, which becomes of a dense white in moist air, and boils at  $248^\circ \text{F}$ . It is of great value as a mordant in dyeing.

The mosaic gold, or *aurum musivum* of the electricians, which is of great service in exciting the electrical machine, is an impure bisulphuret of tin. It is prepared by exposing to a low red heat a mixture of 12 parts tin, 6 of mercury, and 7 of sulphur. There remains a brilliant, dark golden body in scales, and of a greasy feel, which is the mosaic gold.

## CHROMIUM.

Chromium is a hard, grayish-white, brittle metal of sp. gr. 5.9, and exceedingly infusible. Its symbol is Cr, and equivalent 28.19. It is not employed in the metallic state, but its oxides are used as colors.

The sesquioxide ( $\text{Cr}_2\text{O}_3$ ) is of a fine green color, and used in staining glass—the second oxide, chromic acid ( $\text{CrO}_3$ ), is a powerful acid, isomorphous with sulphuric acid. It consists of red crystals, which are very deliquescent, and are readily reduced by organic and other matters into the sesquioxide. Its salts with potash and lead are of a fine orange color; the latter (*chromate of lead*) is much used as a pigment. The bichromate of potash, which has a deep yellow color, is employed in dyeing.



VANADIUM, TUNGSTEN, MOLYBDENUM, OSMIUM and COLUMBIUM are rare metals, scarcely known, and of no practical value.

#### TITANIUM.

Titanium is a metal resembling copper in appearance, but it is extremely infusible, and not used in the arts. It is associated with many iron ores in small quantities. Its symbol is Ti, and equivalent 24.3.

Its oxide, *titanic acid* ( $\text{TiO}_2$ ), is a white insoluble substance, employed in coloring enamels.

#### URANIUM.

Uranium is scarcely known in the metallic state. Its symbol is U, and equivalent 217.26°.

There are three oxides: the *protoxide* ( $\text{UO}$ ), formerly supposed to be the metal; this is a brown powder, and possesses basic properties;—the *black oxide* ( $\text{U}_4\text{O}_5$ ); this is black, and is used to give a black color to porcelain;—the *peroxide* ( $\text{U}_2\text{O}_3$ ) is of a yellow color when hydrated; it forms fine yellow salts, and is used to strike this color in glass and porcelain staining.

#### COPPER.

The ores of copper are abundant, especially the oxide, carbonate and sulphuret; native copper is also common, especially in the north-western territory.

In its reduction, the first object is, by roasting in the open air, to convert the copper of the ore into an oxide; this is next mixed with charcoal, and reduced in the furnace.

Copper is a reddish-yellow metal, of great tenacity and ductility, and very malleable. Its fusing point is about  $2000^\circ \text{F.}$ , and sp. gr. 8.96. It is one of the best conductors of heat and electricity. Exposed to the air, it becomes coated with oxide, but is not affected to any great depth. Its symbol is Cu (from *cuprum*), and equivalent 31.7.

It forms two oxides. The *suboxide* or *dioxide* ( $\text{CuO}_2$ ), which forms the red coating on fresh rolled copper. This also occurs in minerals, in beautiful ruby-red crystals. It is used to stain glass of a red color. The *protoxide* ( $\text{CuO}$ ) is a black powder when dry, but in the hydrated state, is of a pale blue. It is used in organic analysis, to supply oxygen to the substances submitted to heat, for it is reduced with great facility by carbon or hydrogen, but not by heat alone. This is the basic oxide, most of the salts of copper containing it. It stains glass of a fine green color.

The disulphuret of copper ( $\text{Cu}_2\text{S}$ ) is an ingredient of copper pyrites, one of the most abundant ores. Chlorine, iodine, bromide, and cyanogen, form compounds with copper, but they are not at present employed.

Copper is readily detected in solution—ammonia and caustic potash strike a deep purplish blue with it; sulphuretted hydrogen throws it down as a black precipitate; and yellow prussiate of potash, as a brown precipitate. Some of the solutions yield a precipitate of metallic copper, on a clean piece of iron, placed in them. Its compounds are nearly all of a green or blue color. Its salts stain the flame of a spirit lamp or blow-pipe of a green color.

The salts of copper are all more or less poisonous; they are irritants, produce vomiting, purgation and gastro-enteritis. Some are escharotic, and therefore disorganize the stomach. The antidote, which is to be employed at once, and is of more service than even the stomach-pump, is the white of egg. Albumen forms with these salts an insoluble body, which, if soon removed from the stomach, exerts no injurious effects. Yellow prussiate of potash has also been recommended, but we prefer albumen.

*Salts of Copper.*—The protoxide of copper unites with nearly every acid, and forms a large number of salts; some of these have already been mentioned in the chapter on acetic acid, and a few remain to be considered.

*Carbonates of Copper.*—Carbonate of soda precipitates a solution of copper, of a light blue color, which, by warming, becomes granular and of a rich green; this has the composition  $\text{CuO}, \text{Co}_2 + \text{CuO}, \text{HO}$ , or is a mixture of the protocarbonate with the hydrated oxide of copper. This is prepared as a pigment, and has the composition of the mineral called malachite. *Verditer*, made by decomposing nitrate of copper by chalk, is a hydrated dicarbonate. No neutral protocarbonate is yet known.

*The Sulphate of Copper.*—This is the blue vitriol of commerce; it is found in beautiful blue rhomboidal crystals, having the formula  $\text{CuO}, \text{SO}_3 + 3\text{Aq}$ . It is soluble, has a styptic and cupreous taste, and is decomposed at a high temperature. It combines with potash and ammonia, forming deep blue, double salts. That with ammonia, the ammonio-sulphate of copper (*cuprum ammoniatum*), is of a rich color, and capable of crystallizing; it is used as a test for arsenic, and as an antispasmodic and tonic in medicine; the dose is from gr. ss to gr. iv, two or three times a day, and it has been much recommended in functional epilepsy.

Sulphate of copper is a violent emetic in the dose of gr. x; it is astringent and tonic in less doses, and in the dilute state. But

its affinity for albumen is such that it is escharotic, and seldom used except externally. It is employed in the electrotype, and in the arts for various purposes. In contact with metallic copper, it becomes converted into the disulphate.

*The Nitrate of Copper* forms deep blue, deliquescent crystals, which are exceedingly corrosive.

*The Arsenite of Copper* is Scheele's green, formed by bringing the ammonio-sulphate of copper in contact with arsenious acid. It is poisonous, and used as a pigment.

## LEAD.

This metal is derived, for the most part, from the sulphuret called Galena, and which abounds in Missouri, and Derbyshire, England. It is reduced by roasting in a reverberatory furnace.

Lead is a soft, bluish-gray metal, very ductile and malleable, but of little tenacity or elasticity. Its sp. gr. is 11.45, and its melting point  $610^{\circ}$  F.; at a white heat it boils and volatilizes. Exposed to the air, it becomes coated with a blackish film of suboxide, but it is little acted on by acids, except the nitric acid. Its symbol is Pb (*plumbum*), and equivalent 103.7. Lead is extensively employed in the arts, and in assaying.

*Four oxides are known*, of which the protoxide only is basic. The *suboxide* ( $\text{Pb}_2\text{O}$ ) is the black-gray body which forms the tarnish of metallic lead, and the scum on the surface of melted lead. The *protoxide* ( $\text{PbO}$ ) is litharge; it is prepared by heating lead or the carbonate to a dull red heat in a current of air; it is of a pale yellow color, heavy, sparingly soluble, and fusible; it forms colorless salts, with nearly all the acids. The *red oxide*, or red lead, used as a pigment, and in the manufacture of flint glass, appears to be a mixture of the protoxide and binoxide. The *binoxide* ( $\text{PbO}_2$ ), called the puce oxide, is a deep brown powder; it is decomposed at a red heat, and not used except in the laboratory to convert sulphurous into sulphuric acid.

The *iodide of lead* is a beautiful yellow substance, of a silky lustre; it has been recommended by Velpeau in the treatment of scrofulous swellings. The dose is from gr. ss to gr. ij in pill.

The soluble salts of lead are readily detected by the action of sulphate of soda, which yields a white heavy precipitate; by sulphuretted hydrogen, which throws down a black sulphuret of lead; by iodide of potassium and by chromate of potash, which yield rich yellow precipitates.

The soluble salts of lead and the carbonate are more or less poisonous. They affect the intestines, producing costiveness, colic, and in severe cases, intusussception; and also the nervous

system, producing partial paralysis. The antidote is dilute sulphuric acid, or solution of the sulphate of soda. The vapors of white lead factories, and of white paint, are sufficient in some constitutions to induce poisoning; hence this effect has been called painter's colic, or *colica pictorum*.

**SALTS OF THE PROTOXIDE OF LEAD.**—The principal compounds of lead used in medicine are the acetates, which have been described in the article on acetic acid.

*Carbonate of Lead*;  $\text{PbO}, \text{CO}_2$ .—This is the white lead of the painter; it is a soft, white, insoluble powder, of considerable weight, and readily soluble in acids, and to a limited extent in water containing carbonic acid in solution. It occurs in crystalline needles as a mineral.

It is made on an immense scale, in various ways, for the purposes of commerce, as a paint, and for the preparation of other salts of lead; but it is little used in medicine. It is powerfully poisonous, producing painter's colic.

It has been supposed that this substance is formed in lead cisterns, which are hence unfit for domestic purposes;—that the carbonate of lead, dissolved by the carbonic acid present in all water, renders the fluid a slow poison. This effect would arise if the water contained carbonic acid only, but this is never the case; there is nearly always some amount of sulphates, which serve to encrust the cistern with an insoluble coat of sulphate of lead, that protects the metal from all further action by the carbonic acid of the water. It may be a wise precaution to allow the new cistern to be exposed to the action of water for some weeks before use, or to add a little sulphate of soda to the water first admitted; but these precautions are scarcely necessary.

*The nitrate of lead* is found in opaque white octahedrons, which are soluble and without water of crystallization. It is used as a reagent in the laboratory. It is converted into a subnitrate by the action of ammonia.

*The sulphate of lead* is a white ponderous amorphous powder, insoluble in water and acids, and inert.

## BISMUTH.

Bismuth is found native; it forms cubic crystals of considerable lustre, a grayish-red color, and very brittle. Its sp. gr. is 9.9, and it melts at about  $500^\circ \text{F.}$ , and volatilizes at a high temperature. Exposed to the air, it burns with a bluish flame into an oxide. It is easily dissolved by nitric acid. Its symbol is Bi, and equivalent 71.0.



There are two oxides of bismuth: the *protoxide* ( $\text{BiO}$ ), formed by heating the subnitrate; this is an insoluble yellow powder, and the base of the salts of bismuth;—the *peroxide* ( $\text{Bi}_2\text{O}_3$ ) is a brown instable body.

The *chloride of bismuth* is a corrosive butyraceous substance.

*Salts of bismuth.*—The only salts of bismuth much known are the nitrate and subnitrate; the latter is used in medicine.

The *nitrate* is formed by dissolving bismuth in nitric acid; it forms large, colorless, transparent crystals, which are decomposed by the action of water.

The *subnitrate* is made by pouring the above solution when cold into a large quantity of pure water, when a brilliant white, crystalline powder is formed, which is the subnitrate. This was formerly much used as a cosmetic, under the name of pearl powder and magistery of bismuth, but after long use it turns the skin brown, and renders it harsh.

It is used in medicine in cases of gastralgia, obstinate vomiting, and as a tonic. The dose is from gr. iv to gr. x, but as much as a scruple has been given three times a day.

## MERCURY.

Mercury or quicksilver is found native, and as a sulphuret. The metal is well known, and distinguished by its fluidity, brilliant white appearance, permanence in the air, and high sp. gr. of 13.54. It freezes at  $39^\circ \text{F.}$ , and boils at  $620^\circ \text{F.}$ , volatilizing without change, so that it can be readily distilled. But if exposed to the air for a long time, at a considerable temperature, it becomes converted into the red oxide of mercury, but is again reduced at a red heat. Its symbol is  $\text{Hg}$  (from *hydrargyrum*), and equivalent 101.4, but some authors make it 202.0; hence there has arisen much confusion in the nomenclature of its compounds.

It is much used in the arts in the preparation of amalgams, silvering mirrors, the separation of gold and silver from their ores, and the preparation of the mercurial remedies. It is readily dissolved by nitric acid even in the dilute state, and in the cold.

When mercury is triturated with lard, or with saccharine matters, it is reduced to a fine black powder, which is the active agent in the blue pill, mercurial ointment and hydrargyrum cum cretâ. In this state it appears to be dissolved by the juices of the stomach, and to enter the circulation, being a mild and valuable preparation.

*The Oxides of Mercury.*—There are two oxides, the *suboxide*, or, according to some, the *protoxide*—and the *peroxide*, also called the binoxide, but well known by its characteristic red color.

The *suboxide*, or *gray oxide* ( $\text{Hg}_2\text{O}$ ) is readily prepared by adding lime, potash or ammonia to the nitrate. It is a dark gray, heavy powder, insoluble, of basic properties, and slowly decomposed by the action of light into metallic mercury, and the protoxide. It is the substance thrown down when lime water is added to calomel, in the preparation of the black wash.

The *protoxide of mercury* or *red oxide*, *red precipitate*, *nitric oxide*,  $\text{HgO}_2$ , is prepared by heating strong nitric acid on mercury, and evaporating to dryness. Whilst hot, it is of a dark red, but becomes of a lighter red as it cools, and is crystalline; it is slightly soluble, and has an acrid, caustic, and metallic taste. Indeed, prepared in this way, it is caustic from the presence of an excess of nitric acid, and is used by the surgeon as a dressing to indolent ulcers, and to destroy luxuriant and unhealthy granulations. It is basic, forming salts, but is decomposed by a red heat into mercury and oxygen.

The yellow precipitate, formed by adding lime water to a solution of corrosive sublimate, in the preparation of the yellow wash or *Aqua phagedenica*, is a hydrated protoxide.

The *chlorides of mercury* are of considerable medical interest. The *subchloride*, or mild chloride ( $\text{Hg}_2\text{Cl}$ ), is calomel. It is a heavy, white, insoluble and tasteless powder, volatilizable at a temperature below redness, and subliming in brilliant yellowish crystals. The powder used in medicine, was formerly prepared by pounding and washing the sublimate, but it is not had by subliming the calomel into a chamber filled with steam. This is Howard's calomel, or the hydrosublimate of mercury.

It is slightly changed by exposure to the light, acquiring a light brown color, which seems to be due to the formation of a small amount of suboxide.

Calomel is readily decomposed, the alkalis yielding a black suboxide; these preparations are, therefore, incompatible with it. The medicinal powers, both internally, and externally as a desiccative, are too well known to require further consideration here.

The *protochloride* or *corrosive sublimate* ( $\text{HgCl}$ ), formerly called the bichloride, is one of the most fearful poisons employed in medicine. It is usually found as white, transparent prismatic crystals, soluble in 16 parts of cold and three of boiling water, and of a powerful metallic taste. It melts at  $509^\circ \text{F.}$ , and volatilizes at a higher temperature, subliming into a crystalline mass.

Corrosive sublimate is decomposed by the alkalis and lime; these precipitate a yellow, insoluble body, which we have mentioned as the hydrated protoxide. It combines with proteinous bodies, and owes its activity as a poison, and as an antiseptic body, to this action—these compounds being insoluble and almost indestructible. It has a disposition, like the chlorides of platinum and

gold, to form double salts with other chlorides—these are often termed hydrargyro-chlorides.

*Sal Alembroth* is an instance of this kind; this consists of  $\text{HgCl} + \text{NH}_4\text{Cl} + \text{HO}$ , or hydrargyro-chloride of oxide of ammonium. The *white precipitate* of pharmacy, a compound made by adding excess of ammonia to corrosive sublimate, consists of corrosive sublimate with amidide of mercury, or  $\text{HgCl} + \text{Hg}, \text{NH}_2$ .

In *poisoning* by corrosive sublimate, or any of the preparations of mercury, the white of eggs is the antidote. This acts by forming an insoluble compound, which should, however, be removed from the stomach by the stomach pump, as soon as possible.

There are *two iodides* of mercury. The *subiodide*,  $\text{Hg}_2\text{I}$ , is a greenish-yellow, insoluble body; it is readily formed, by adding a solution of iodide of potassium to the sub-nitrate of mercury. It sublimes in red crystals, and is partly decomposed by the action of light. It has been recommended as a remedy, in cases where syphilis and scrofula are conjoined; the dose internally is gr. i; but it is a powerful irritant. The ointment contains one-eighth by weight of the iodide.

The *iodide of mercury*,  $\text{HgI}$ , also called the deutiodide and red iodide, is a brilliant scarlet powder, of great weight, sp. gr. 6.32, and insoluble. When rapidly heated, it volatilizes, subliming into yellow crystals, which become red, when scratched by a hard body. When slowly sublimed, the crystals are of a scarlet color.

Like corrosive sublimate, it has a tendency to unite with the alkaline iodides, forming hydrargyro-iodides. It is a powerful irritant and caustic, resembling corrosive sublimate, but not being so active. It has been recommended in cases in which syphilis and scrofula are combined; the dose internally is gr.  $\frac{1}{16}$ . The ointment is a very active, stimulating preparation; it contains one-eighth of the iodide. It is particularly recommended in ophthalmia tarsi.

There are *two bromides* and *two cyanides*, corresponding to the foregoing bodies, which are, however, but little or not at all employed in medicine. The *cyanide of mercury* ( $\text{HgCy}$ ) is the only one of much importance, it forms beautiful, pearly, colorless, square prisms; it is slightly soluble, volatile, and of considerable weight. It closely resembles corrosive sublimate in its properties, and has been mentioned as an antisymphilitic remedy in the dose gr.  $\frac{1}{16}$  to gr.  $\frac{1}{8}$  in solution. But it is so poisonous, that it is doubtful whether it should be used. It is employed in the laboratory, for the preparation of cyanogen and hydrocyanic acid.

The *sulphurets of mercury* are the black or sub-sulphuret, ( $\text{Hg}_2\text{S}$ ), and the red or protosulphuret ( $\text{HgS}$ ). The former is little used; it is the Ethiop's mineral of the older pharmaco-

pœias; the latter is cinnabar; it is found in nature as the most abundant ore of mercury, and is occasionally used in mercurial fumigations.

Cinnabar is a brilliant red, insoluble body, the powder of which forms vermilion; it is of great weight, and readily sublimes. According to Orfila, it is inert when pure.

*Tests for the preparations of Mercury.*—The mercurial preparations are volatile; mixed with a little charcoal, or with charcoal and carbonate of soda, and heated in a glass tube, the mercury is readily reduced. The metal is also precipitated from its soluble salts, by a clean plate of copper. Solution of caustic potash, or ammonia, precipitates it from its soluble compounds, as a black or yellow powder, according as it is the suboxide or protoxide. Solution of albumen is precipitated by all the soluble salts of mercury.

**THE OXYGEN SALTS OF MERCURY.**—The nitrate and sulphate are used in medicine. The acetate was formerly employed in the pills of Keyser.

*The Neutral Nitrate of Mercury* is made by the action of cold dilute nitric acid on mercury. It forms transparent, crystalline rhombs, which are extremely caustic, and are used as an escharotic to fungous granulations. There is an officinal ointment. This is a nitrate of the suboxide, its formula being  $\text{Hg}_2\text{O}, \text{NO}_5 + 2\text{Aq}$ ; it is soluble in a small quantity of water, but in a large excess, it becomes decomposed, forming an insoluble sub-nitrate.

When a little ammonia is dropped into a solution of the nitrate, a black precipitate falls, which is called *Hahnemann's soluble mercury*; its composition is, according to Kane,  $2\text{Hg}_2\text{O}, \text{NO}_5 + \text{NH}_3$ .

If in the preparation of the nitrate an excess of mercury be employed, a crystalline basic salt is deposited after a time; this has the composition  $\text{Hg}_2\text{O}, 2\text{NO}_5 + 3\text{Aq}$ . It is decomposed by water.

*The neutral nitrate of the protoxide* exists only in solution; it is made by dissolving the protoxide (*red oxide*) in cold nitric acid. If the acid be hot, there is formed a crystalline basic salt,  $2\text{HgO}, \text{NO}_5 + 2\text{Aq}$ ; this substance yields to cold water a second basic salt which is of a yellow color and insoluble  $3\text{HgO}, \text{NO}_5 + \text{HO}$ , and to boiling water a red insoluble substance of the formula  $6\text{HgO}, \text{NO}_5$ . The yellow insoluble powder above mentioned is sometimes called the *nitrous turpeth*, and was employed in medicine as an emetic and purgative. The medicine was made by allowing water to stand on the yellow powder and decanting it—the fluid and not the insoluble substance was used.

The *subsulphate*,  $\text{Hg}_2\text{O}, \text{SO}_3$ , is a white crystalline body formed when sulphuric acid is added to a solution of the neutral subni-



trate. The neutral *protosulphate of mercury*,  $\text{HgO}, \text{SO}_3$ , is made by boiling sulphuric acid with the metal to dryness; it is a white crystalline powder.

When the neutral sulphate is mixed with water, it becomes resolved into an acid salt which remains in solution, and there falls a yellow, acrid, basic compound,  $3\text{HgO}, \text{SO}_3$ , which is the yellow sub-sulphate (*hydrargyri sulphas flavus*), or turpeth mineral of pharmacy. This body is known as a violent emetic and errhine; in doses of gr. ss, it is alterative, but rapidly produces ptyalism. It is seldom employed.

By long-continued boiling with water, it loses its nitric acid, and becomes resolved into protoxide of mercury.

## SILVER.

Silver is found native, and as a sulphuret and chloride. The ore being reduced, the silver is separated by amalgamation with mercury. The amalgam is next decomposed by distillation.

Metallic silver is a white, brilliant substance; it is very malleable and ductile, and one of the best conductors of heat and electricity. Its sp. gr. is 10.5, and its melting point upwards of  $1800^\circ \text{F}$ . In the pure state it is so soft that it is alloyed with a small amount of copper to harden it for the purposes of art. Its symbol is Ag (from *argentum*), and equivalent 108.31.

It does not oxydize in the air, but is soon coated with a black crust by sulphuretted hydrogen. Its solvent is strong nitric acid.

There are three oxides of silver, all of which are reduced at a red heat; of these the protoxide ( $\text{AgO}$ ) alone is basic. The haloid salts of silver are of some importance in the arts; they are all affected by light, being decomposed. The *iodide* is the yellow substance employed in the Daguerreotype; it is produced by exposing the silver to the vapor of iodine;—the *chloride* is a white insoluble body which turns black in the light;—the *bromide* is a brownish insoluble substance also used in photography. The cyanide is a brown insoluble powder made by precipitating a solution of nitrate of silver by cyanide of potassium; it is used in the preparation of medicinal prussic acid, and also in electroplating.

Silver is readily recognized in solution by the action of a little hydrochloric acid, which throws down the white chloride as a curdy precipitate. This blackens by exposure to the air. It is also thrown down from its solutions in the metallic state by introducing into them a piece of clean iron, copper, or by mercury.

The *nitrate of silver*,  $\text{AgO}, \text{NO}_5$ , is the only oxygen salt of importance. It is made by the action of strong nitric acid on

silver. In the pure state, it is crystallized in transparent tables, which are readily soluble in water or alcohol. It fuses when heated, and may be cast into the sticks called lunar caustic, but is decomposed at a red heat. It is a well known caustic and astringent, and has been often recommended in epilepsy. When brought in contact with organic matter in the light, it becomes black; hence it is used to dye the hair of a black color, and to mark linen. The leaden hue acquired by patients who take this medicine for any length of time, is due to the same cause. Ammonia first forms a precipitate in the nitrate, but subsequently re-dissolves the precipitate, producing a clear solution of *ammonio-nitrate* of silver, which is a valuable test for arsenious acid.

## GOLD.

This metal is always found native, and is separated from mineral impurities by amalgamation. It is a soft, yellow metal, of great lustre, sp. gr. 19.3. It melts at about 2000° F. It is the most malleable and ductile of the metals, and one of the best conductors of heat and electricity. Its symbol is Au (from *aurum*), and equivalent 199.2.

It is unchangeable in the air, even in the finest fibres, and is not acted upon by any pure acid; but a mixture of the nitric and hydrochloric acids (aqua regia), dissolves it. Chlorine acts upon it directly, forming the chloride of gold. In the divided state, gold forms a black powder, like that of platinum, silver and mercury.

The preparations of gold are little used. The *sesqui-chloride* ( $\text{Au}_2\text{O}_3$ ), formed by the action of nitro-muriatic acid, is a deep yellow, crystalline, and deliquescent salt. This combines with the alkaline chlorides, forming the *auro-chlorides*.

The sesqui-chloride of gold and the auro-chloride of sodium have been employed in medicine as anti-syphilitic remedies, and in cancer. The chloride is said to resemble corrosive sublimate, in its action and power. The dose is gr.  $\frac{1}{16}$  to gr.  $\frac{1}{8}$ , twice a day. The antidote is white of eggs. The auro-chloride of sodium is employed in gilding Daguerreotype plates.

Other preparations of gold, as the iodide, cyanide and oxide, have been mentioned as officinal bodies, but they are inferior to the corresponding salts of mercury, and not used. Indeed, there is some doubt as to their activity, for Velpéau and Bourdeloque have altogether failed to verify the observations of Chrestien, Orfila, and others, concerning their value. The cyanide of gold, a brown, insoluble body, is employed in solution in cyanide of potassium, in the process of electro-gilding.

The haloid salts of gold are all changed by light, and decom-

posed by heat. The oxides, of which there are two, do not form salts with the acids. In these respects, gold resembles platinum, iridium and rhodium.

The presence of gold in a solution, is known by the action of a solution of the protochloride of tin, which strikes a rich purple color (*the purple of Cassius*); and also by the sulphate of iron, which throws down a brown precipitate, which is readily fusible before the blowpipe into a bead of gold.

## PLATINUM.

Platinum is always found native, and usually associated with palladium, iridium, and rhodium. It is a white metal, harder, but of less brilliancy, than silver. Its sp. gr. is 21.5, and it is infusible in the furnace; for its preparation, Dr. Hare's blowpipe is now used, or spongy platinum is alternately heated and pressed, until it becomes solid. It is one of the poorest conductors of heat and electricity amongst the metals. It is malleable and very ductile. Its symbol is Pt, and equivalent 98.84.

Platinum is unchangeable in the air, and is not affected by any of the pure acids, but is dissolved by nitro-muriatic acid, and converted into the chloride. In consequence of its unchangeability, it is much used for chemical vessels, and is an indispensable metal in the laboratory. It exists in three forms: as the hammered white metal; in a porous state, or *spongy platinum*; and in fine powder, *platinum black*.

The hammered metal possesses the property of condensing oxygen and some other gases on its surface, especially when red hot, but in an inferior degree. It is, however, capable of effecting catalytic changes in the vapor of many organic bodies.

*Spongy platinum* is prepared by dissolving the metal in nitro-muriatic acid, and then adding chloride of ammonium to the solution; this forms the insoluble platino-chloride of ammonium, which, heated to redness, leaves a grayish spongy mass of platinum, which is the body in question.

Spongy platinum, introduced into a mixture of oxygen and hydrogen, causes their union, by condensing and bringing the gases together in its pores. In the open air, if a stream of hydrogen be directed on it, the metal becomes red hot. It brings about numerous changes of eremacausis, as the conversion of the vapor of alcohol into acetic acid.

*Platinum black* is the metal in a very finely divided state. It is prepared by mixing a solution of chloride of platinum with an excess of carbonate of soda and sugar, and heating slowly to 212°

F., with frequent agitation. The black powder formed in this operation, is collected on a filter, washed, and gently dried.

It possesses the property of condensing oxygen and other gases, and acts more powerful as a catalytic or oxydizing agent, than spongy platinum. It is used in the manufacture of acetic acid from alcohol in Germany. When formic acid is slowly dropped on it, it becomes converted into carbonic acid by oxydation. Alcohol and ether dropped on it, are changed into acetic acid with the evolution of so much heat as to cause the inflammation of a portion of these fluids.

There are two oxides of platinum, the protoxide,  $\text{PtO}$ , and bin-oxide,  $\text{PtO}_2$ , which are of little consequence, and form salts of an instable nature, readily decomposed by light and heat.

There are also two chlorides, the *protochloride*,  $\text{PtCl}$ , and the *bichloride*,  $\text{PtCl}_2$ . The latter is the common solution of platinum; it is a light-brown, deliquescent solid, exceedingly soluble in water and alcohol. It is most remarkable for the facility with which it is decomposed, and its tendency to unite with the chlorides of the alkalies to form platino-chlorides.

In virtue of this property, it is employed as a test for potash and ammonia, with which it forms insoluble, crystalline, orange-colored salts. With soda, it forms a soluble crystalline salt. The solution of the bichloride is used in organic analysis for the determination of nitrogen, which is first converted into ammonia, and then forms the platino-chloride of ammonium. It has also been introduced into medicine, as a substitute for corrosive sublimate, but is inferior, and not now employed.

The cyanide of platinum, dissolved in a solution of cyanide of potassium, is employed in the electrotype to coat bodies with platinum.

#### PALLADIUM.

Palladium is associated with platinum, and resembles that metal in many respects. It is white, malleable and ductile, almost infusible, and of sp. gr. 11.5. It does not oxydize in the air, but when heated, acquires a purple tint. The metal is somewhat employed by dentists. Its symbol is Pd, and equivalent 53.36.

#### IRIDIUM.

Iridium is a white, brittle metal, almost infusible, and having a sp. gr. of 21.8. Hence it is the heaviest body in nature; it is



not dissolved by any acid, but oxydizes by fusion with nitrate of potash. Its symbol is Ir, and equivalent 98.84.

## RHODIUM.

Rhodium is found in the platinum ores. It is a steel white metal, of great hardness and brittleness; its sp. gr. is 11.0, and it is extremely infusible. It is employed to tip metallic pens, and renders them very durable. Its symbol is R, and equivalent 52.20.

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